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Ikeda et al.

(10) **Patent No.: US 9,470,553 B2**
(45) **Date of Patent: Oct. 18, 2016**

(54) **ROTATION ANGLE DETECTION APPARATUS**

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(73) Assignee: **AISAN KOGYO KABUSHIKI KAISHA**, Obu (JP)

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(22) Filed: **Apr. 15, 2015**

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(30) **Foreign Application Priority Data**

May 20, 2014 (JP) 2014-104691

(51) **Int. Cl.**

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G01B 7/30	(2006.01)
G01D 5/14	(2006.01)
F02D 41/00	(2006.01)
H02K 7/116	(2006.01)
G01D 5/04	(2006.01)
G01P 3/487	(2006.01)

(52) **U.S. Cl.**

CPC ***G01D 5/14*** (2013.01); ***F02D 41/009*** (2013.01); ***G01D 5/04*** (2013.01); ***G01D 5/145*** (2013.01); ***H02K 7/116*** (2013.01); ***H02K 11/215*** (2016.01); *G01P 3/487* (2013.01)

(58) **Field of Classification Search**

CPC G01D 5/14
USPC 324/207.11, 207.22
See application file for complete search history.

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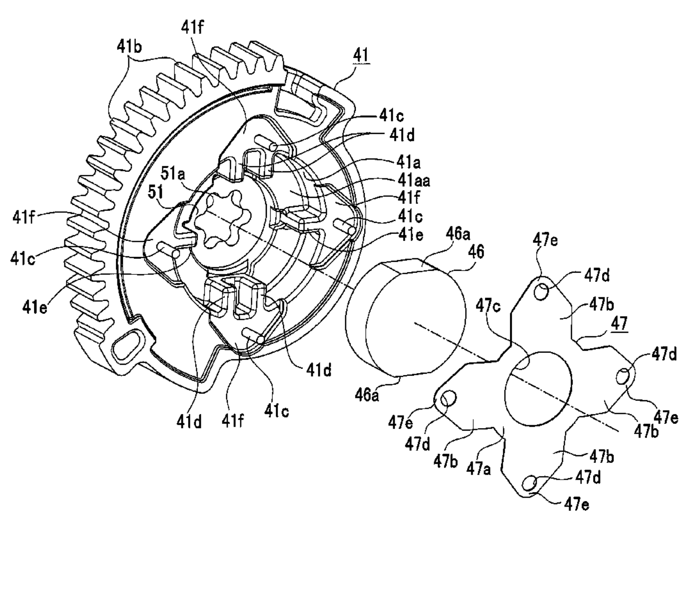
(57) **ABSTRACT**

Rotation angle detection apparatus includes a magnet provided in a main gear and a magnetism detector positioned to face to the magnet. Magnet rotates integrally with main gear and magnetism detector detects changes in magnetic field of magnet so a rotation angle of main gear is detected. Main gear includes bottomed recessed part and plurality of mounting pins arranged in recessed part. Magnet is inserted in recessed part wherein a part of magnet protrudes from an upper end of the recessed part. Magnet inserted in recessed part is pressed against main gear by an elastically deformable retaining plate made of non-magnetic material. An outer portion of retaining plate includes plurality of mounting holes. Magnet inserted in recessed part is pressed against main gear by elastically deformed retaining plate and mounting pins inserted in mounting holes are thermally caulked wherein magnet is secured to the main gear.

14 Claims, 29 Drawing Sheets



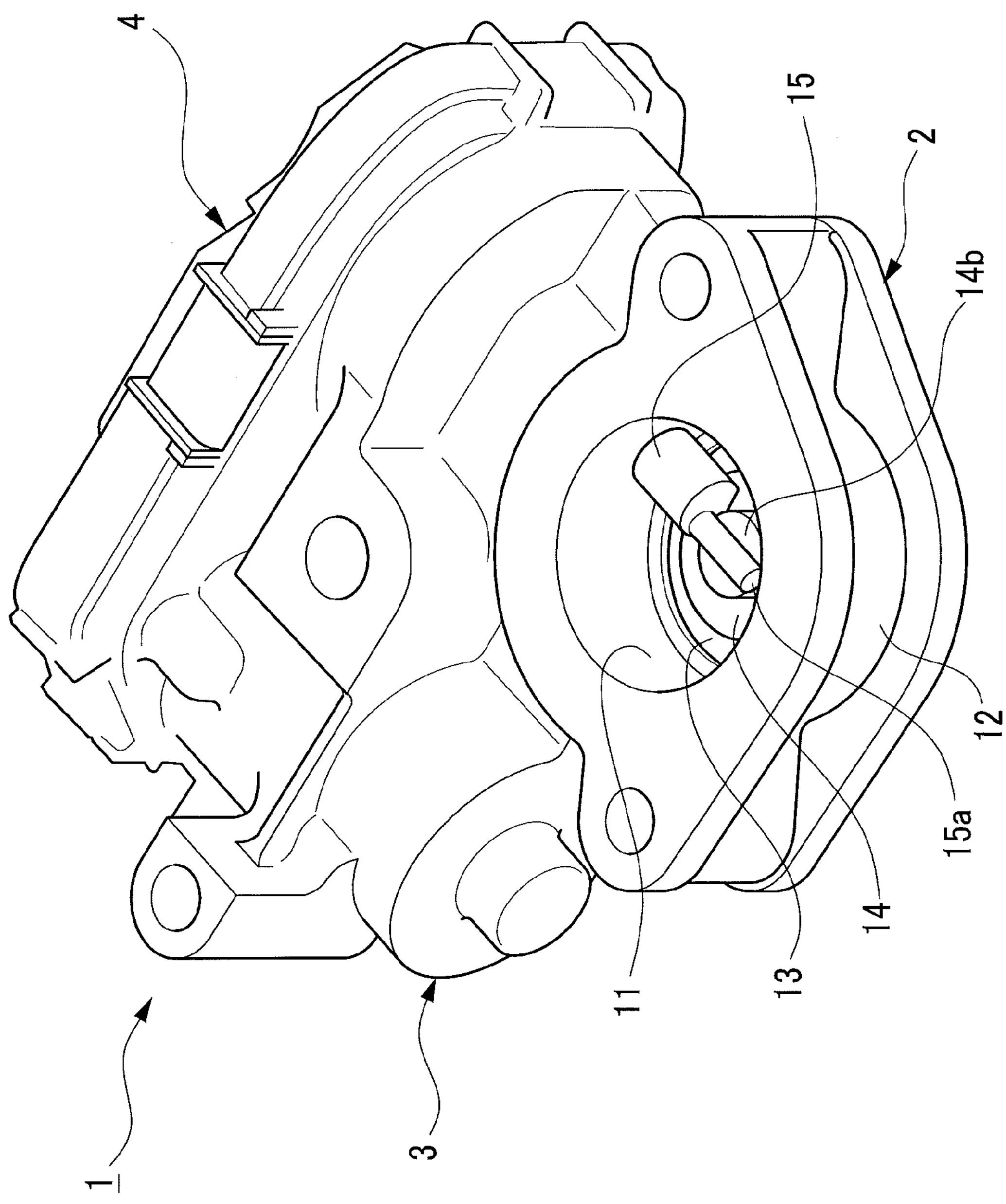


FIG. 1

FIG. 2

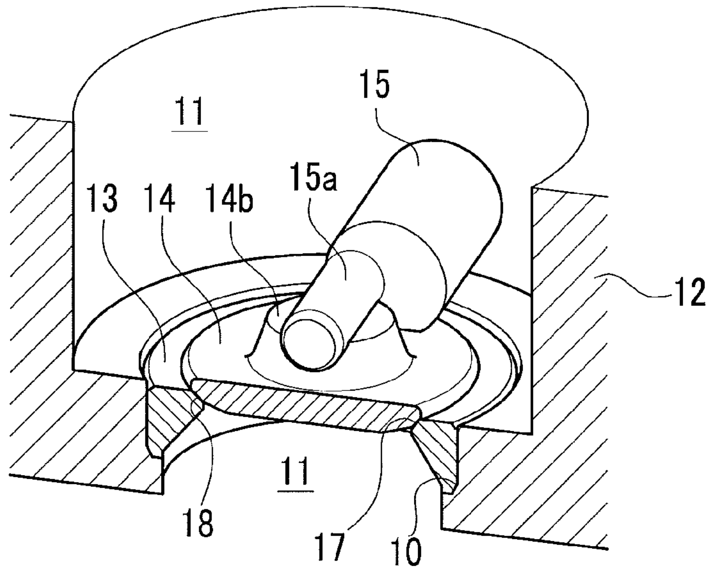

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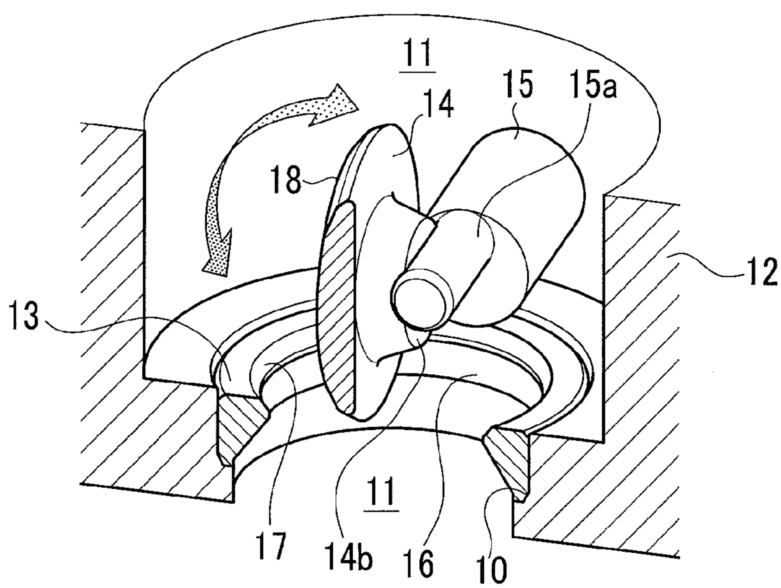
FIG. 3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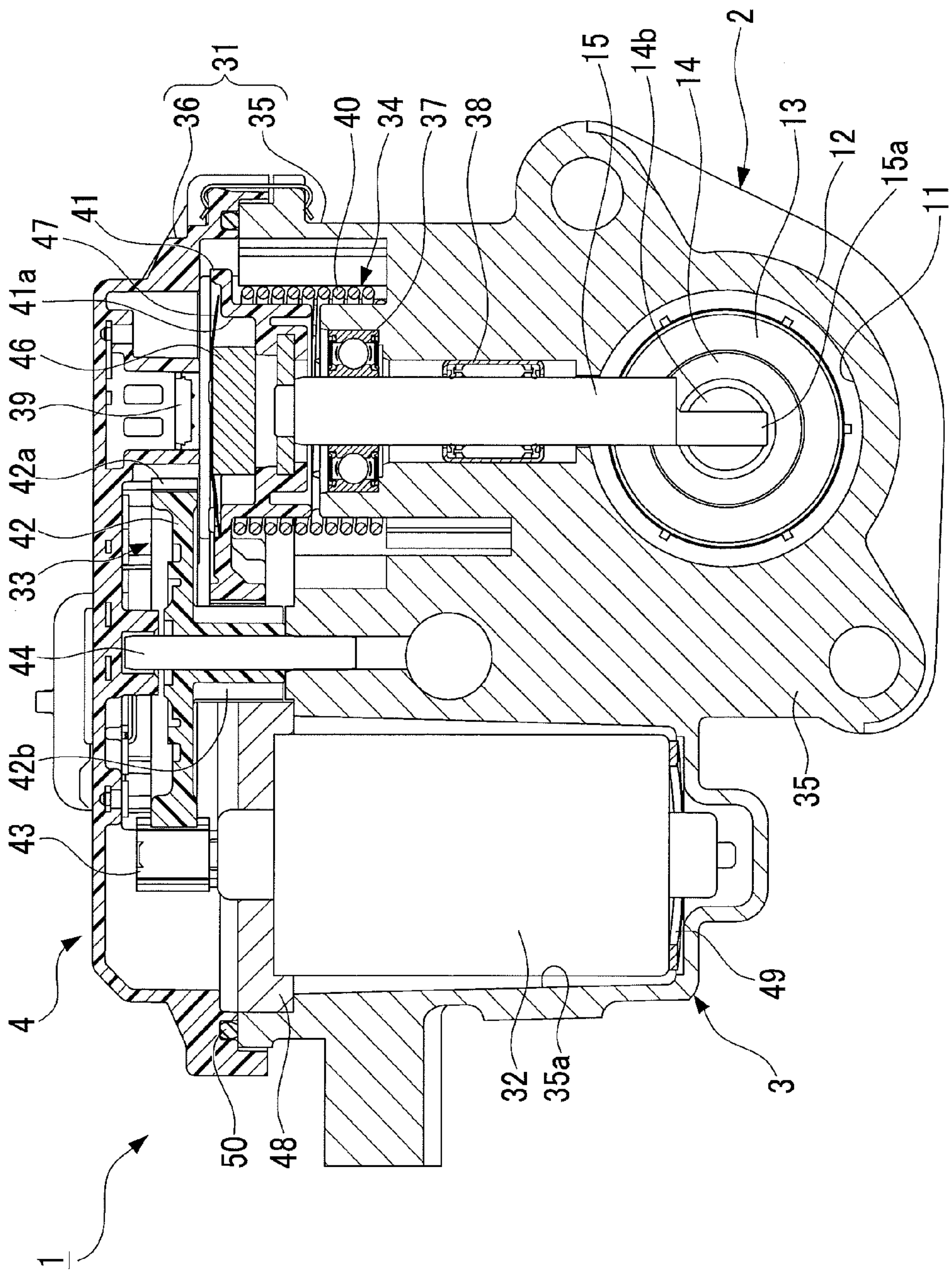
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FIG. 4

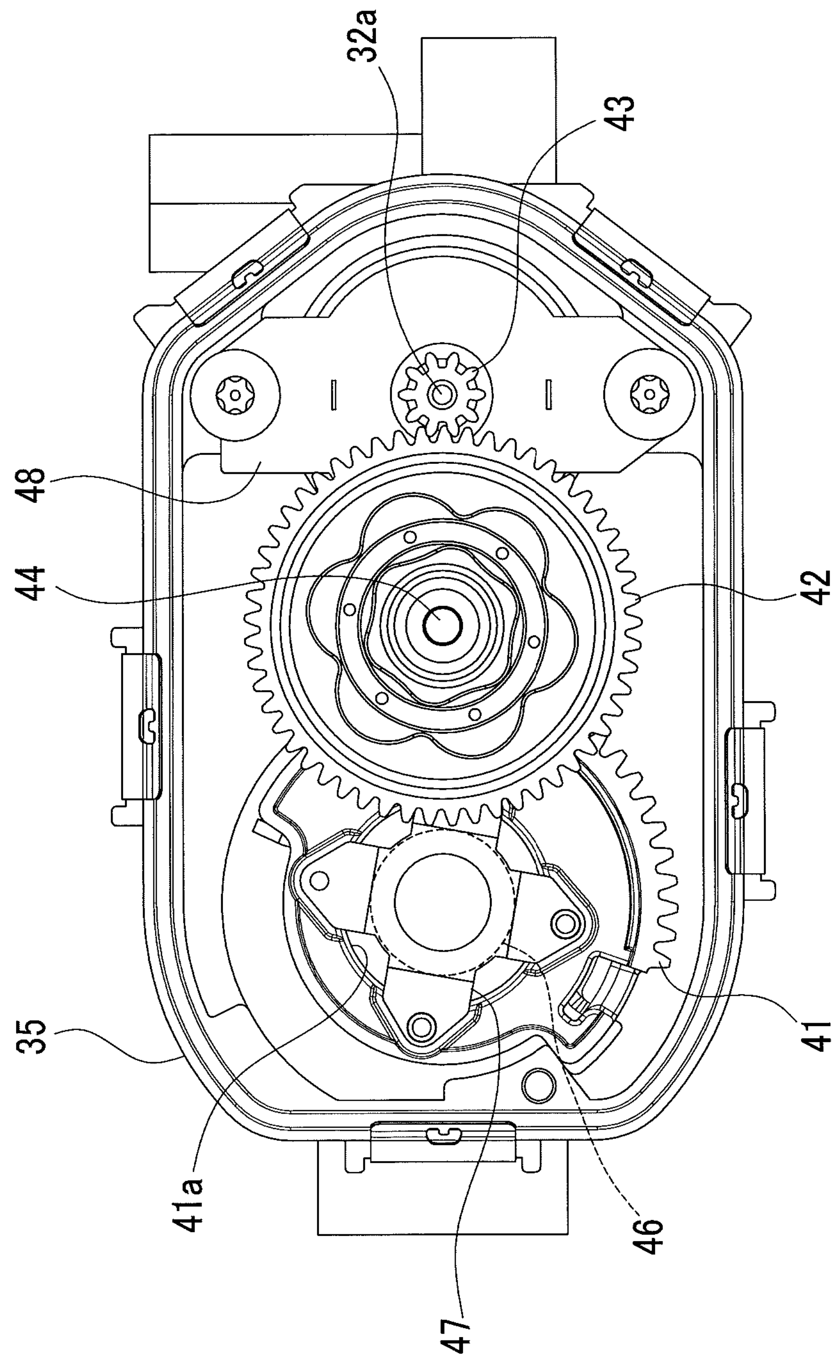
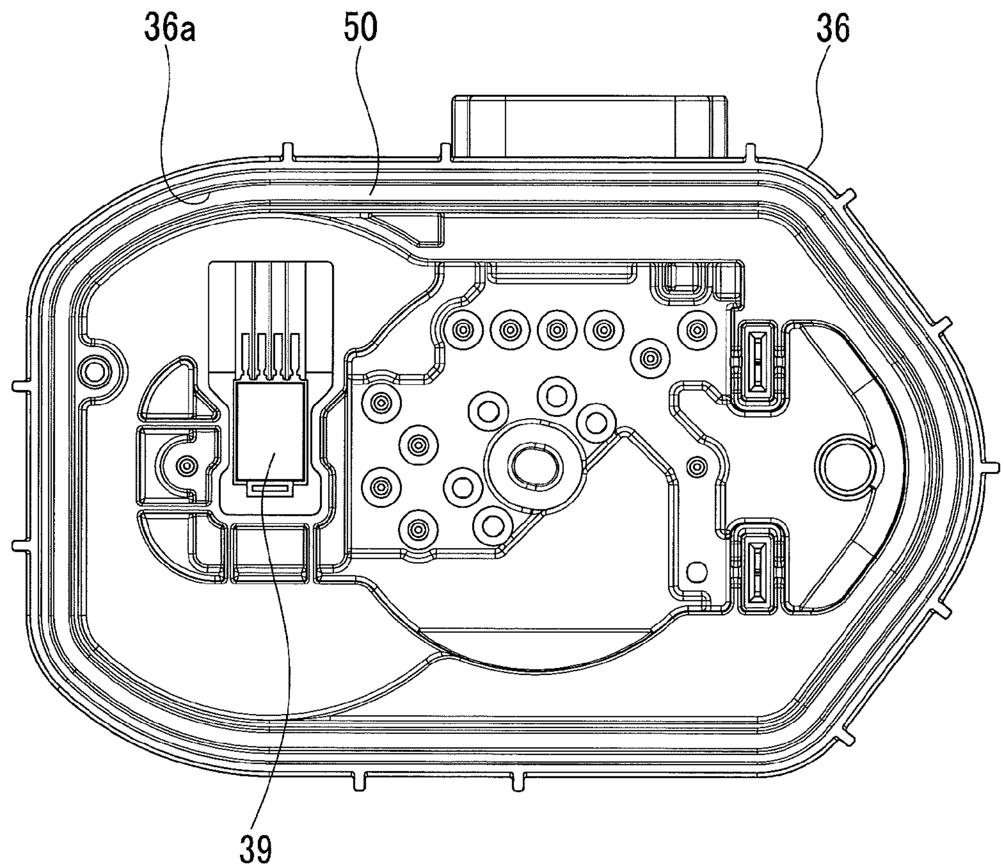


FIG. 5

FIG. 6



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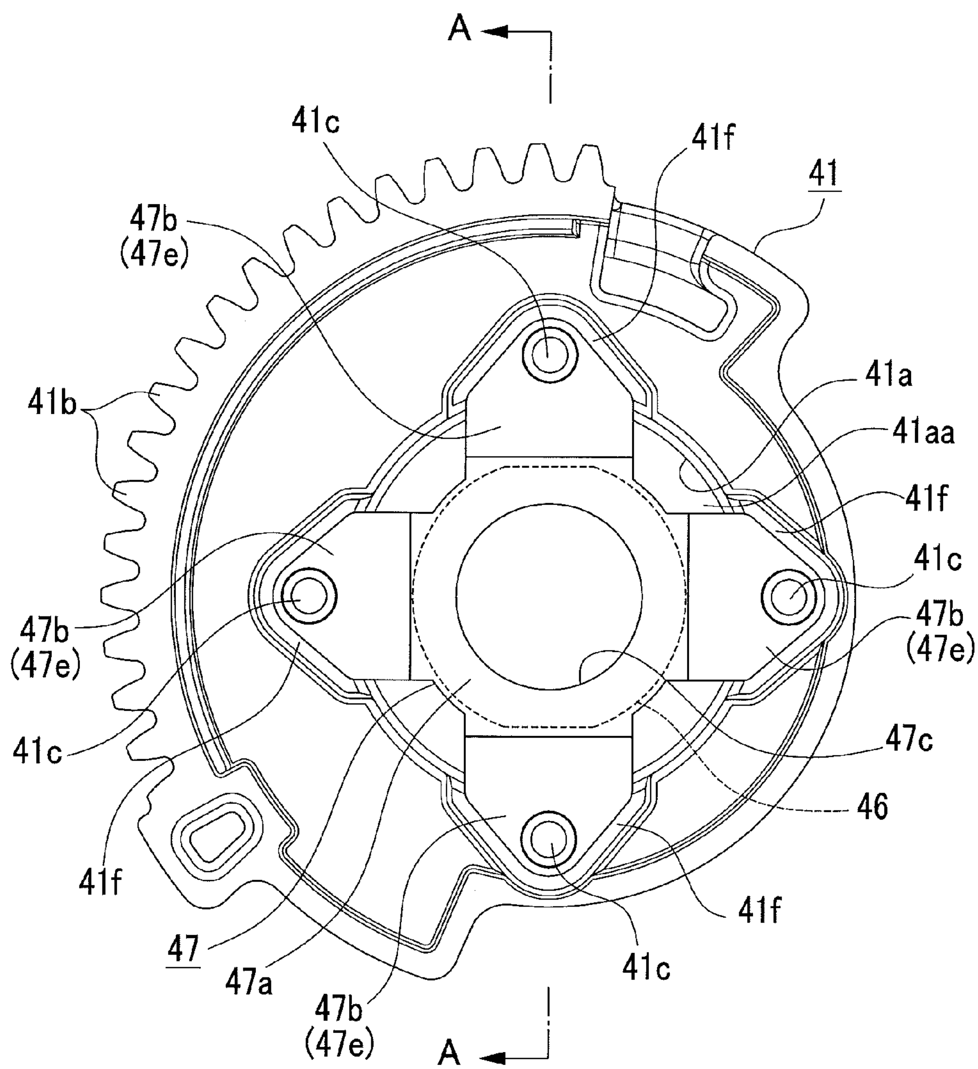
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47a
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(47e)
A

FIG. 8

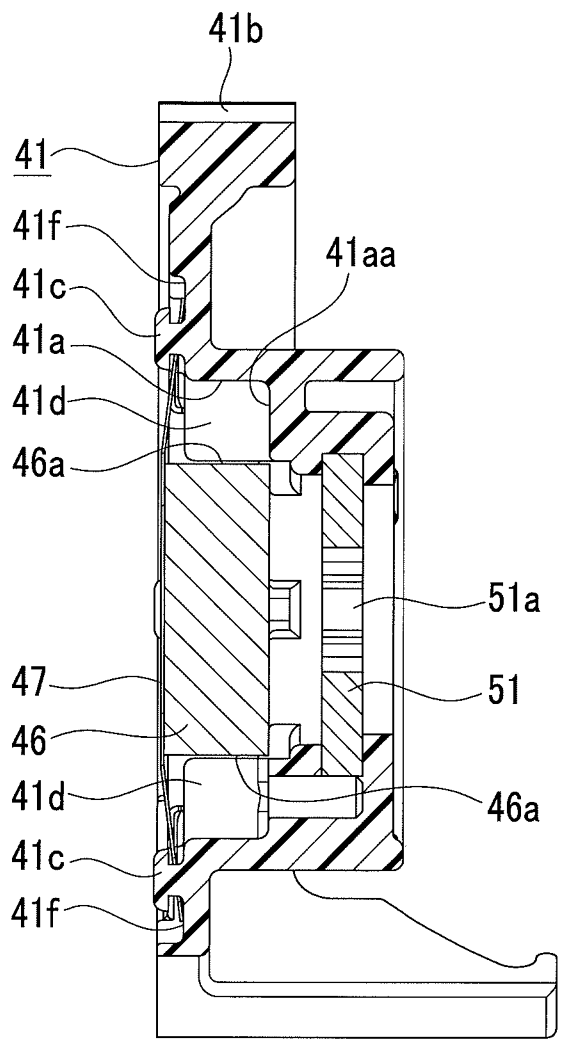
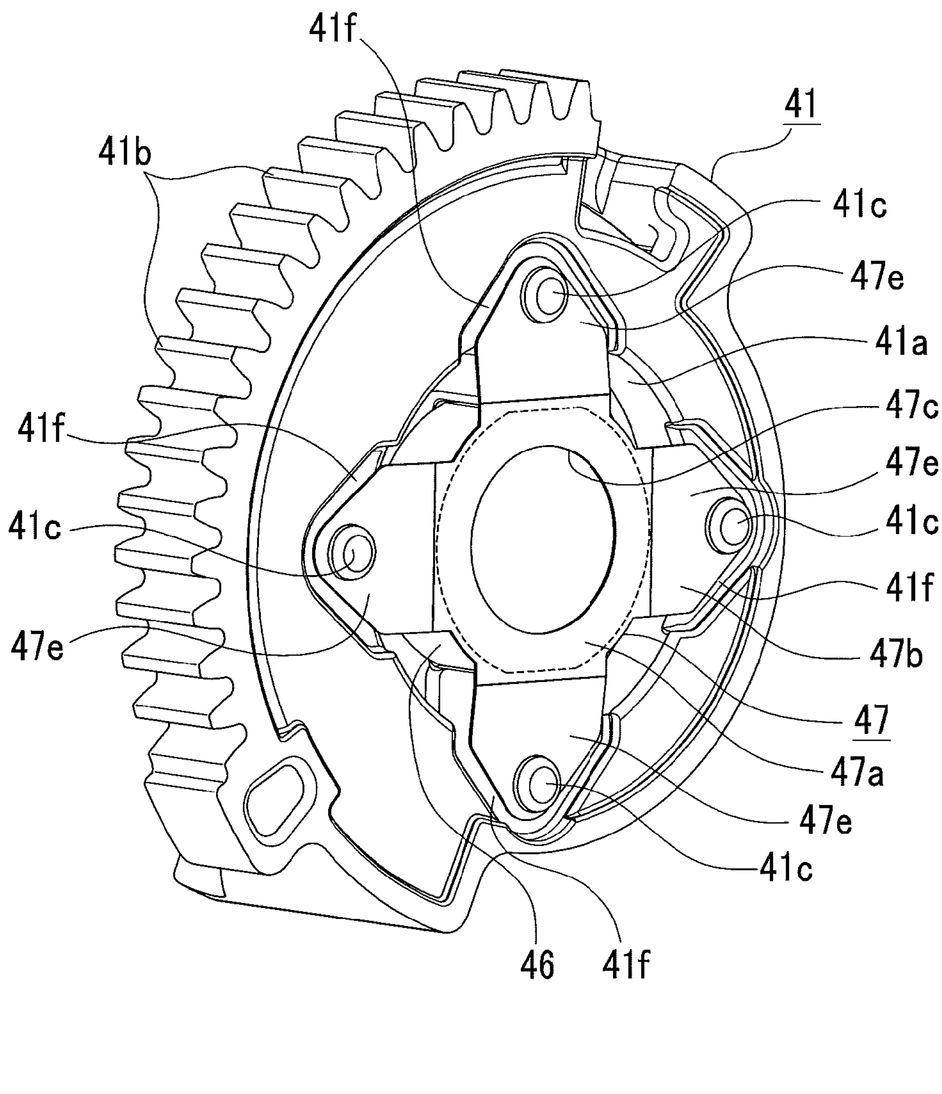


FIG. 9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41f

FIG. 10

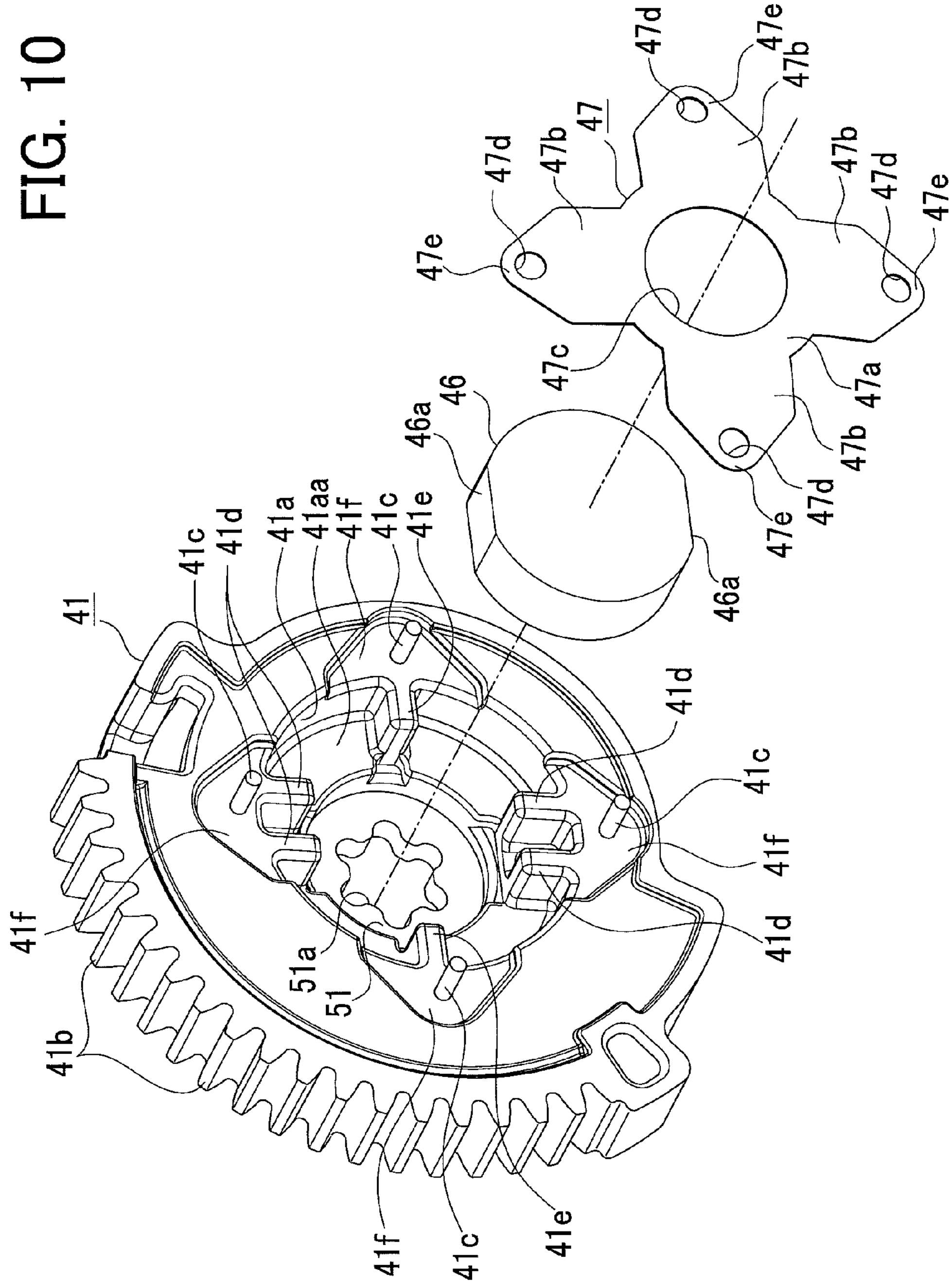
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FIG. 11

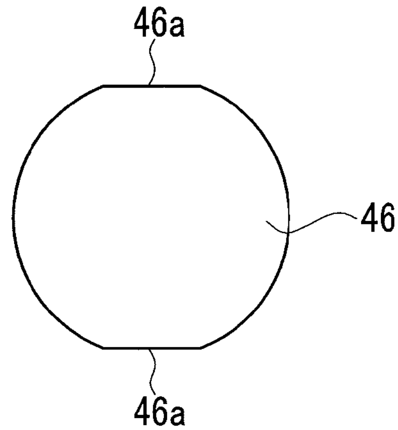
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FIG. 12

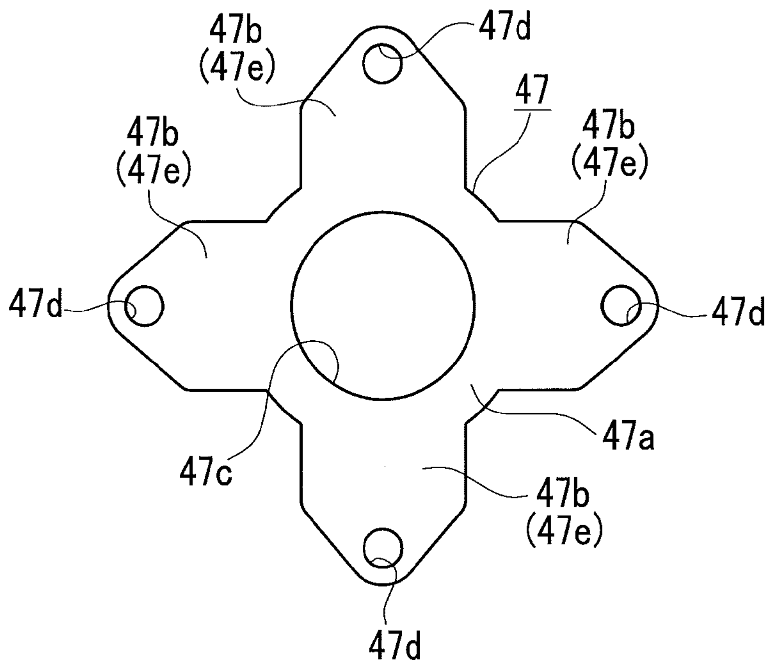
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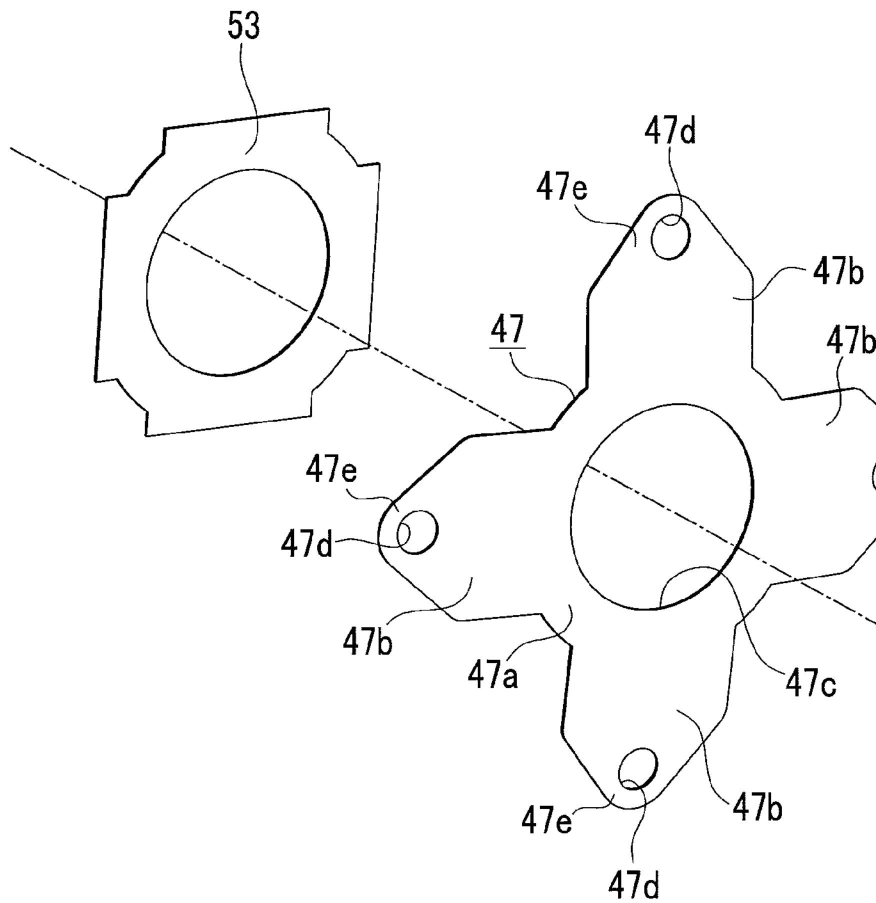
FIG. 13



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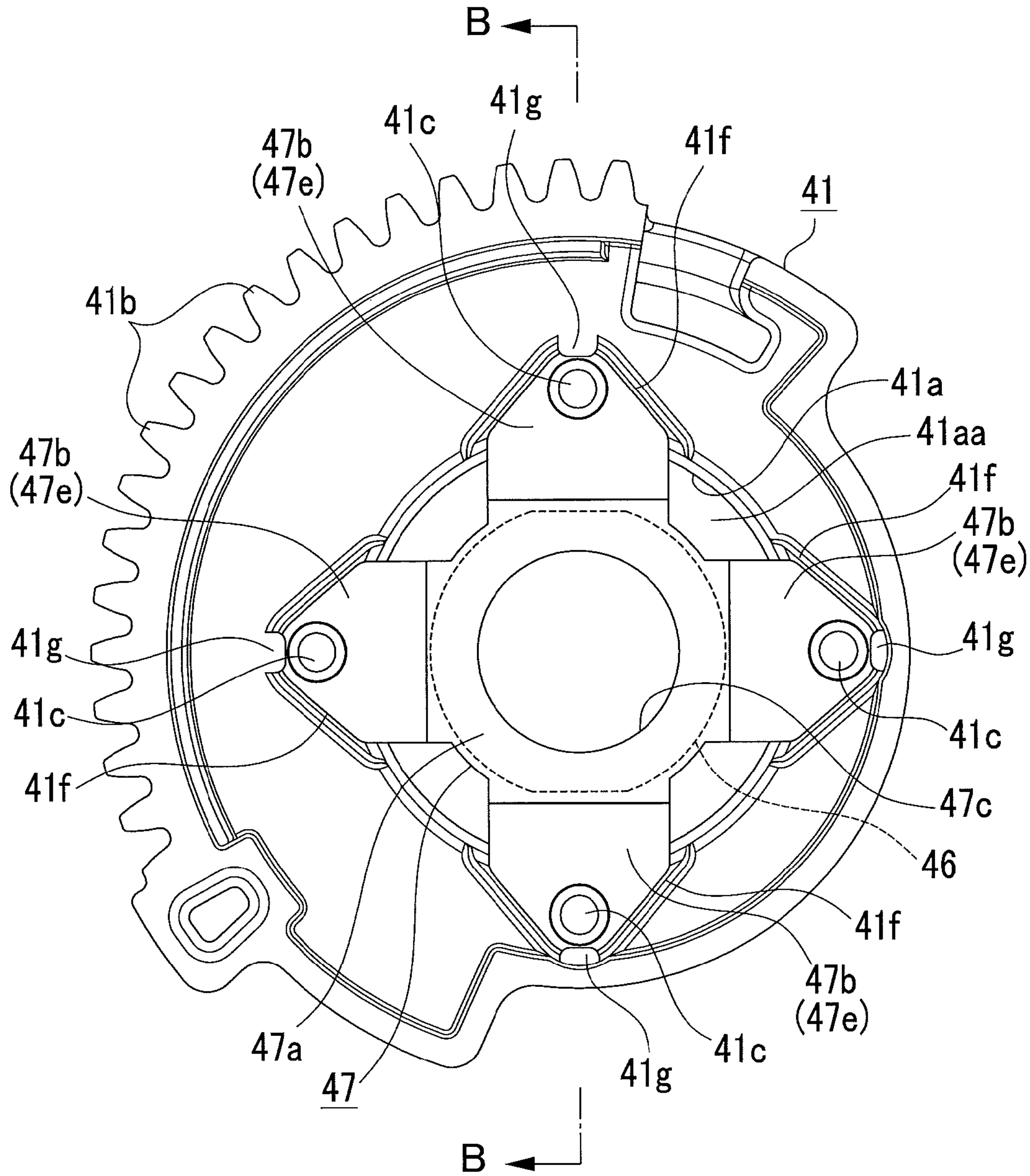

B
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41c
B

FIG. 15

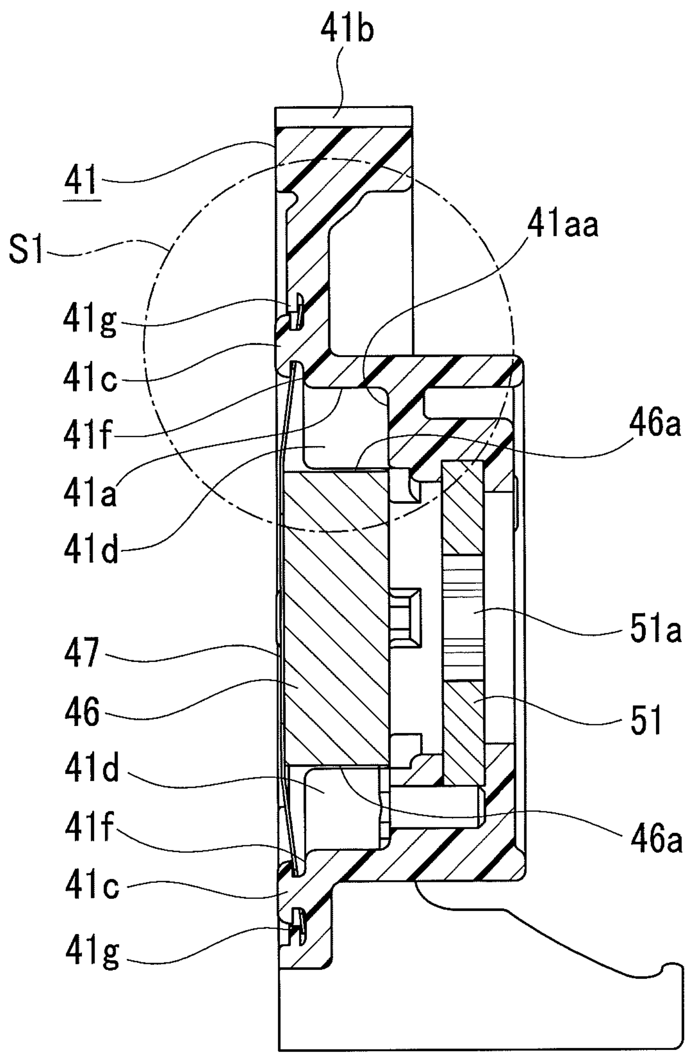
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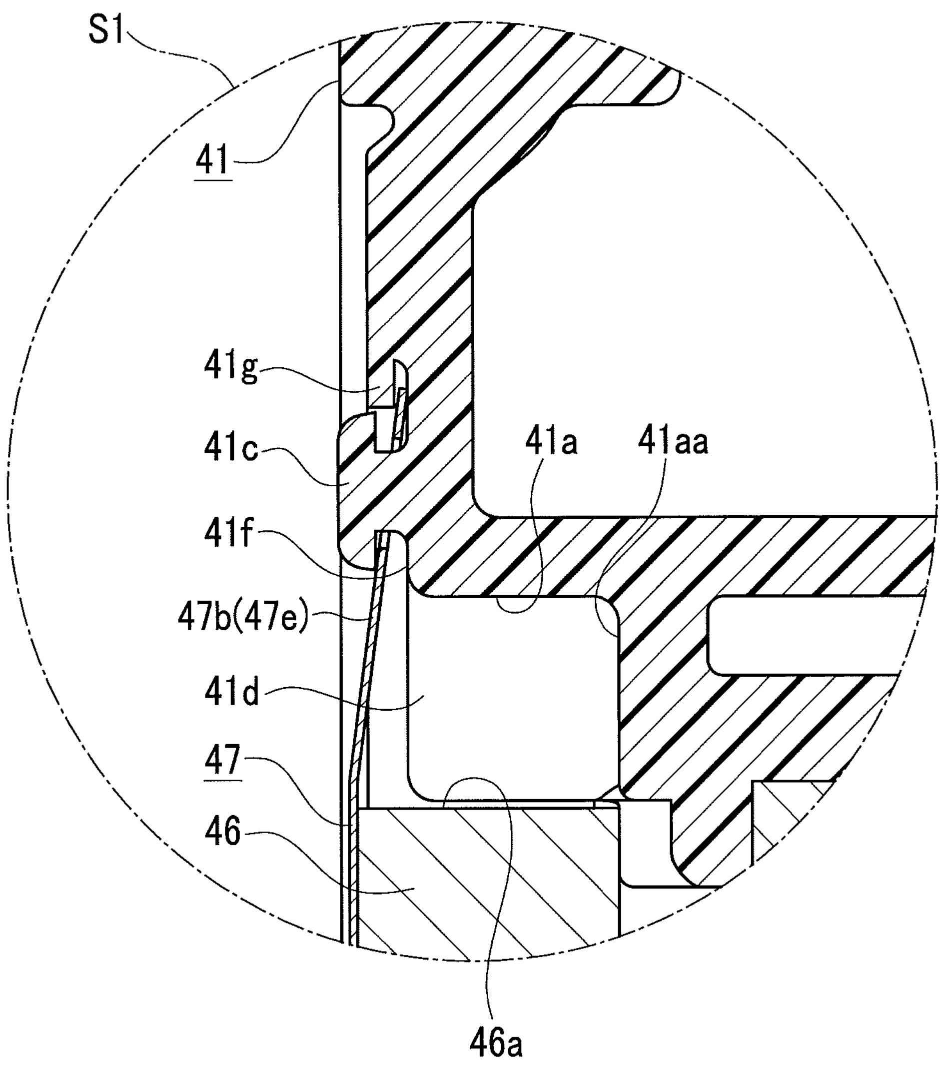
FIG. 16



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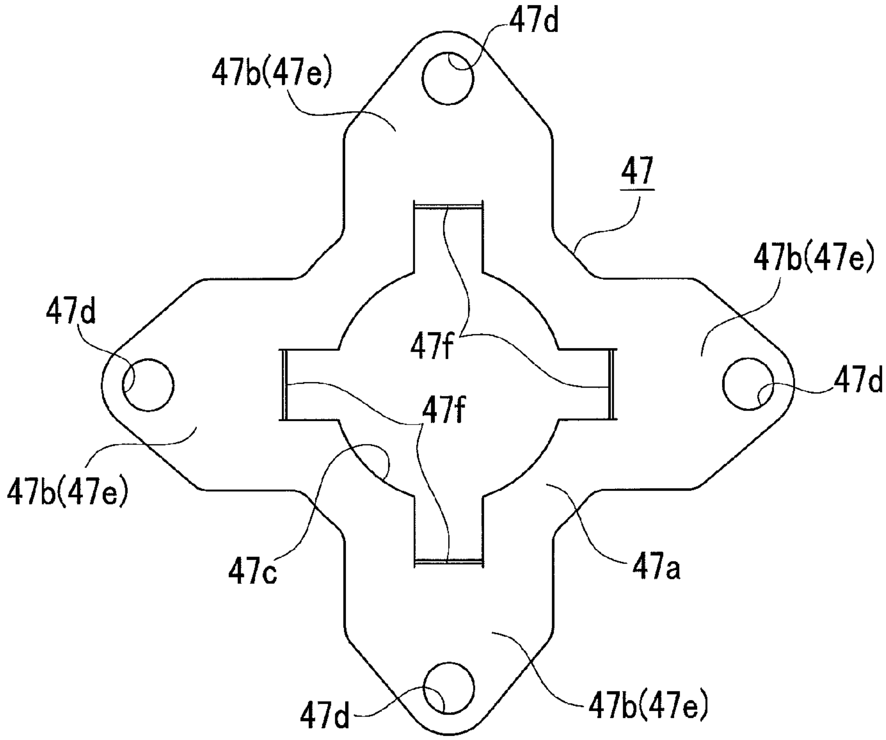
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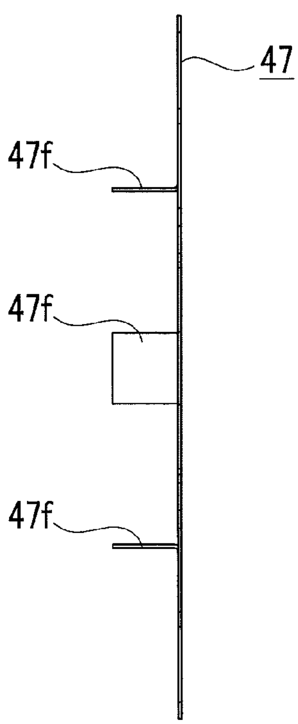
FIG. 18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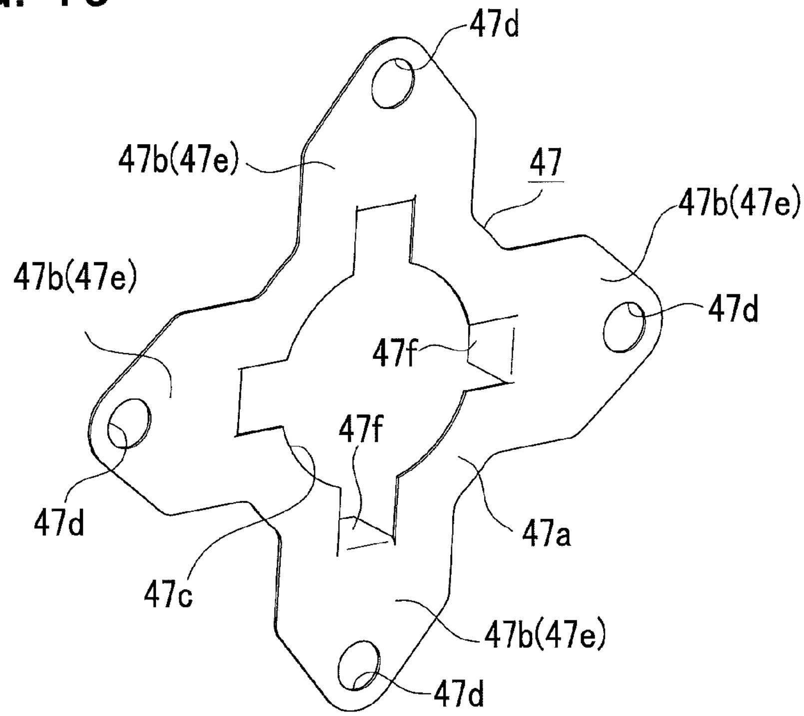
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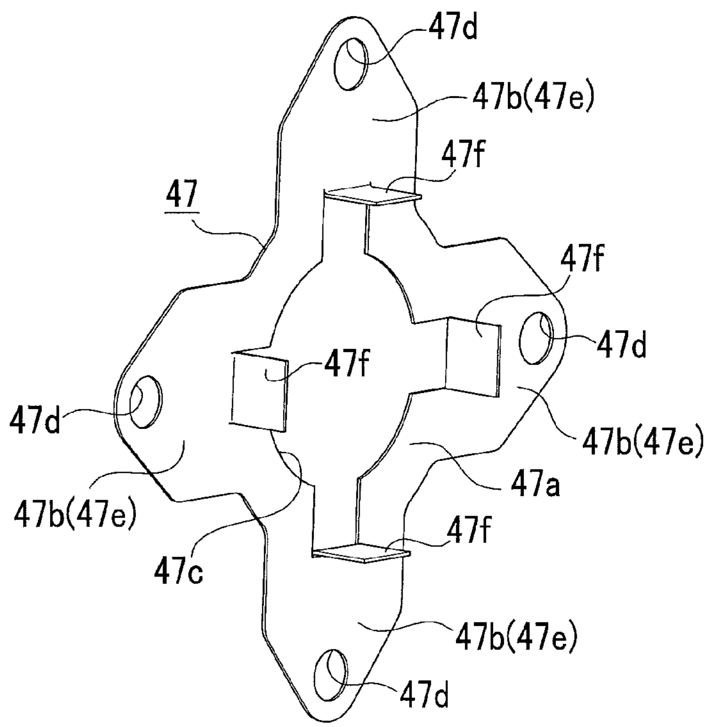
FIG. 20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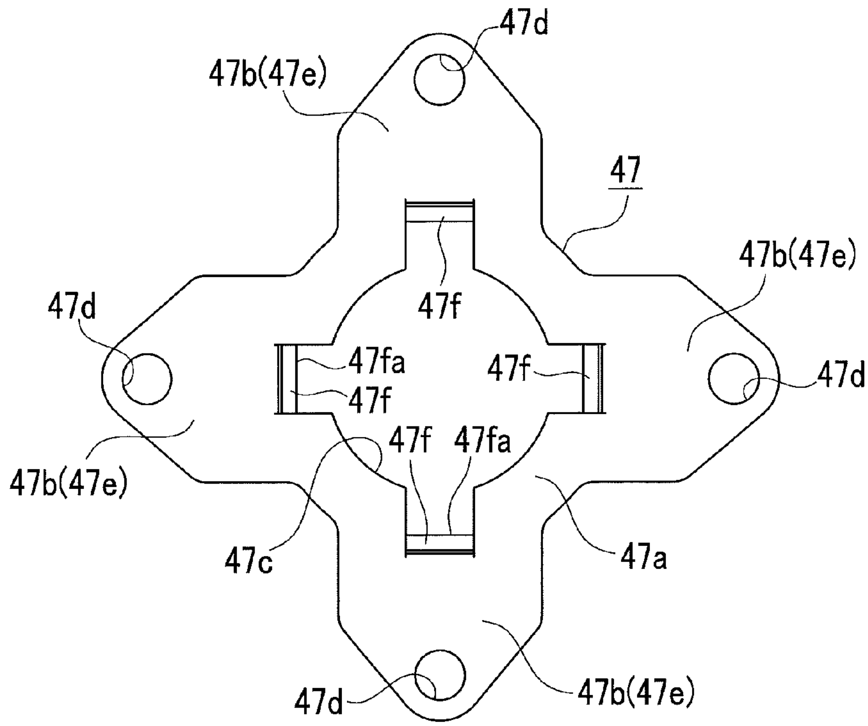
47d

FIG. 21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47b(47e)

FIG. 22

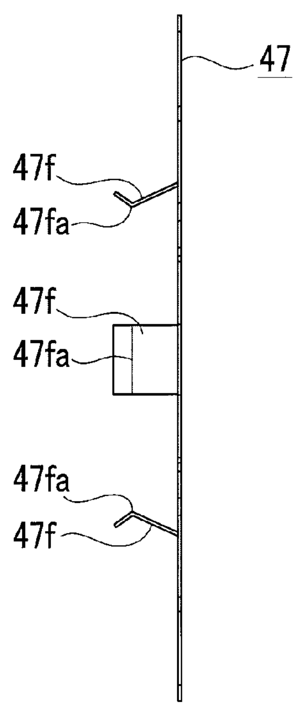
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FIG. 23

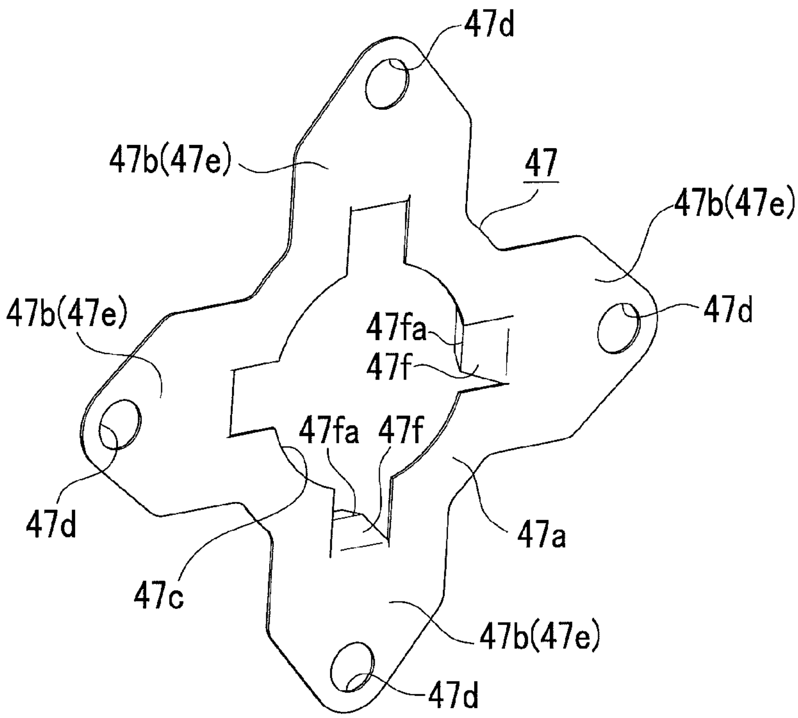
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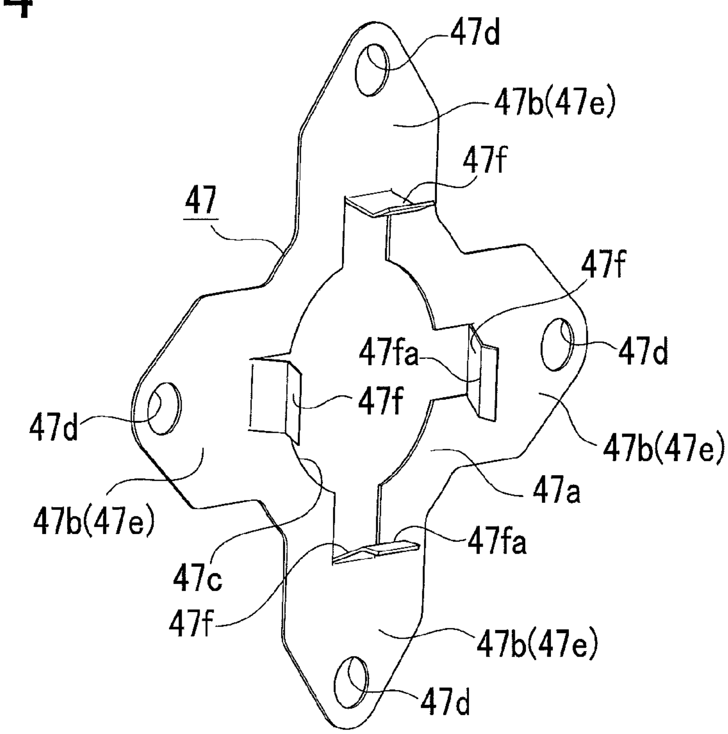
FIG. 24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47d

FIG. 25

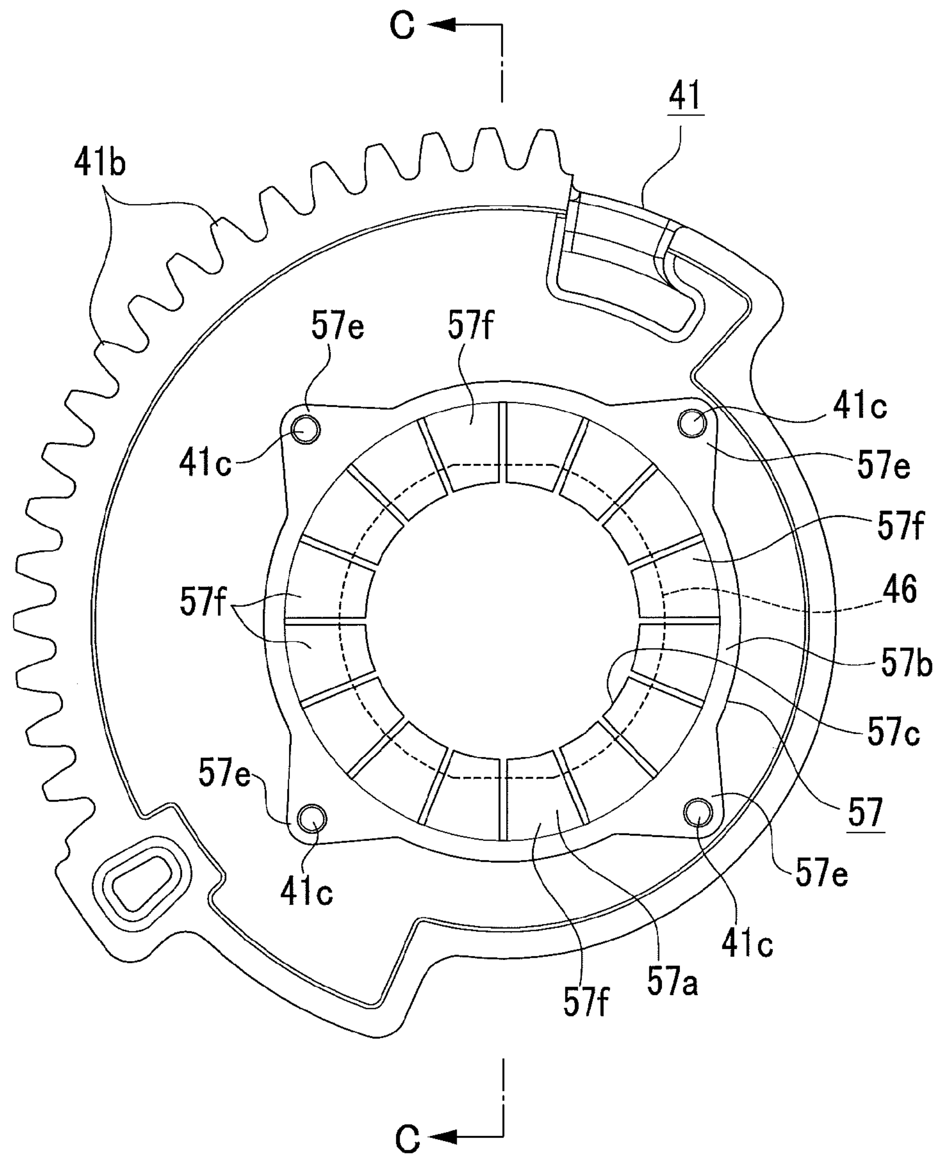
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FIG. 26

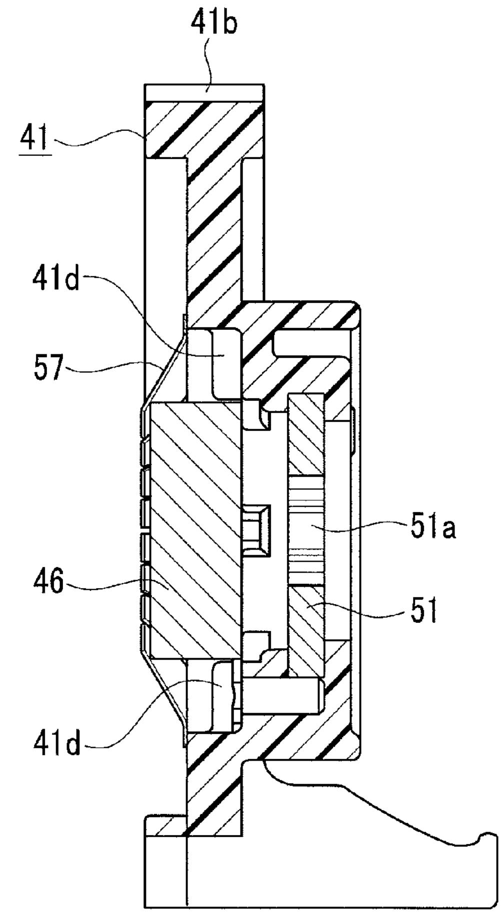


FIG. 27

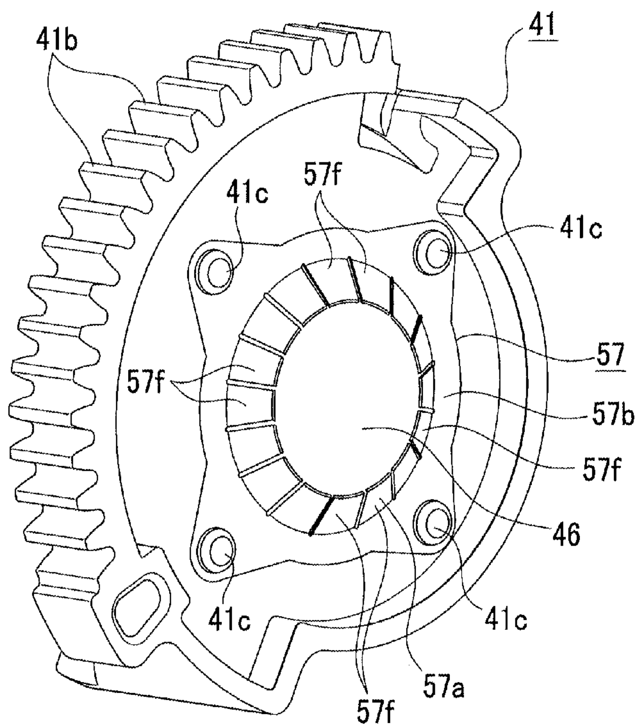
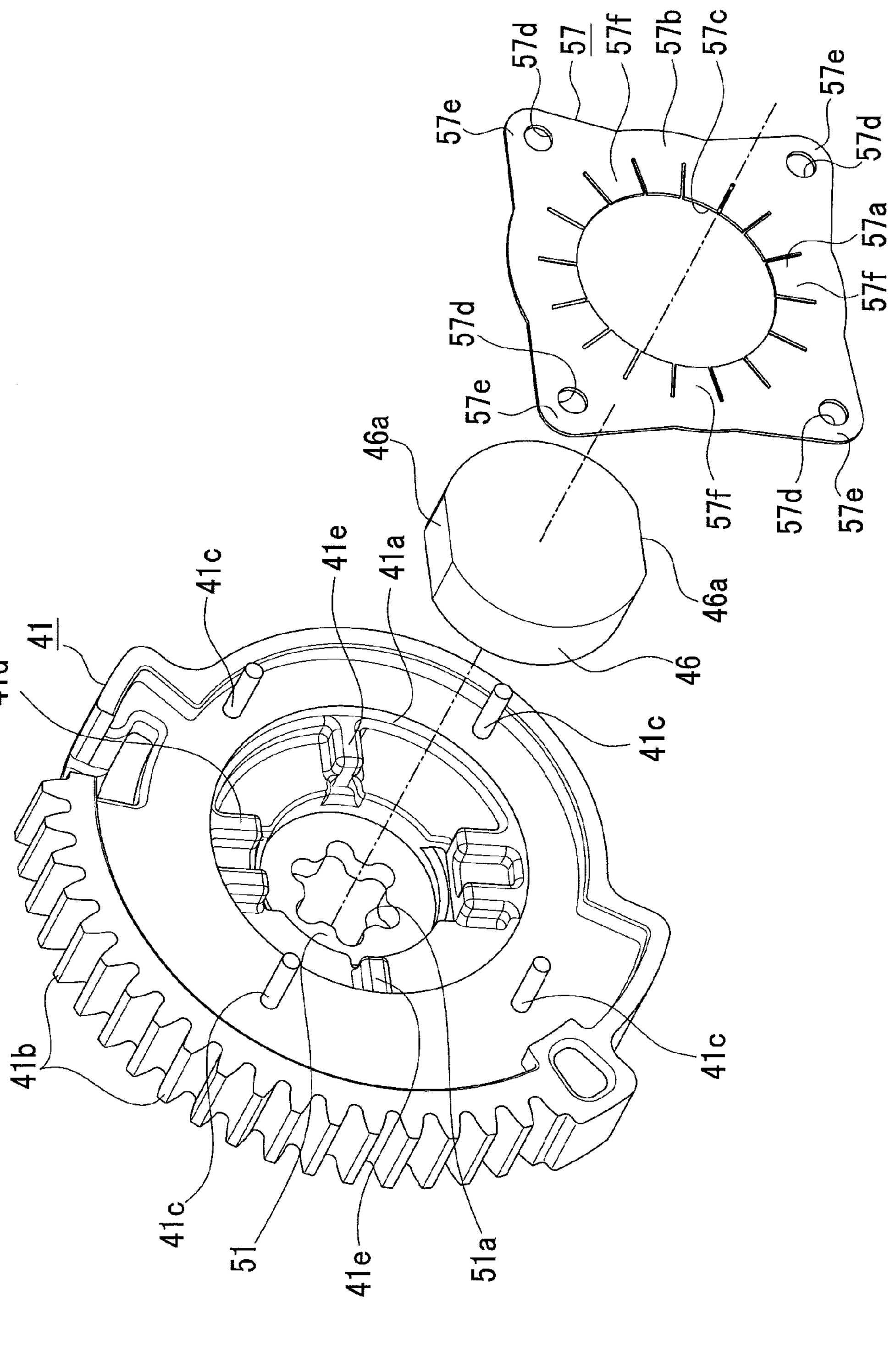


FIG. 28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41b
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41e
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FIG. 29

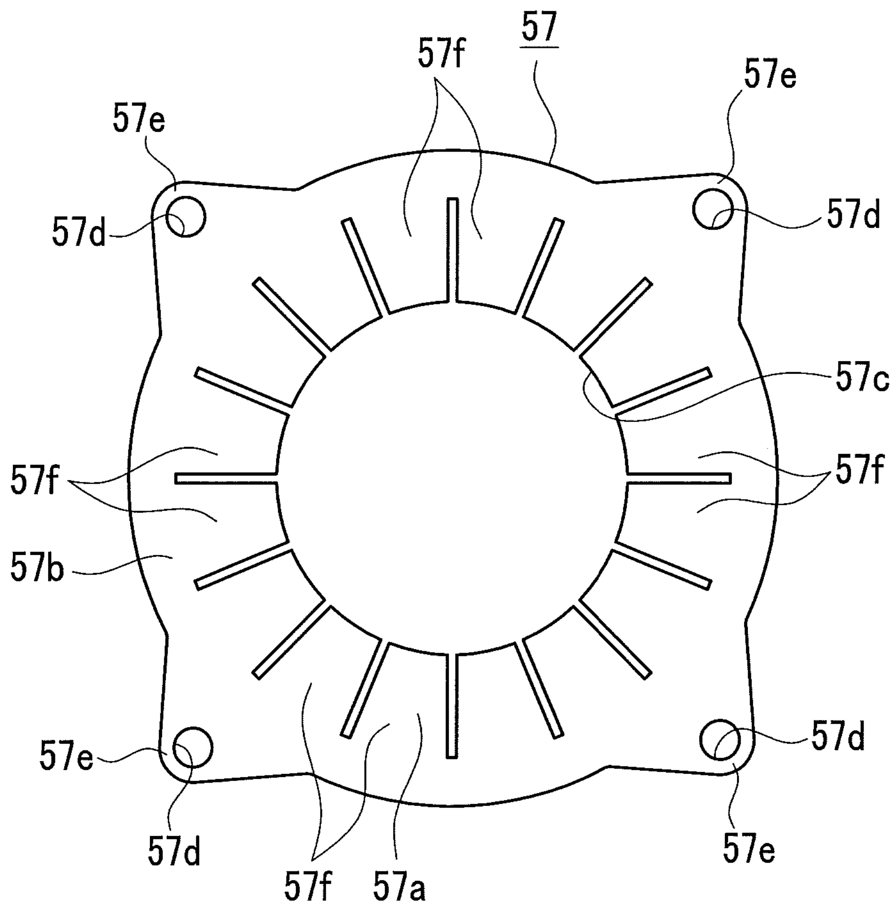

FIG. 30

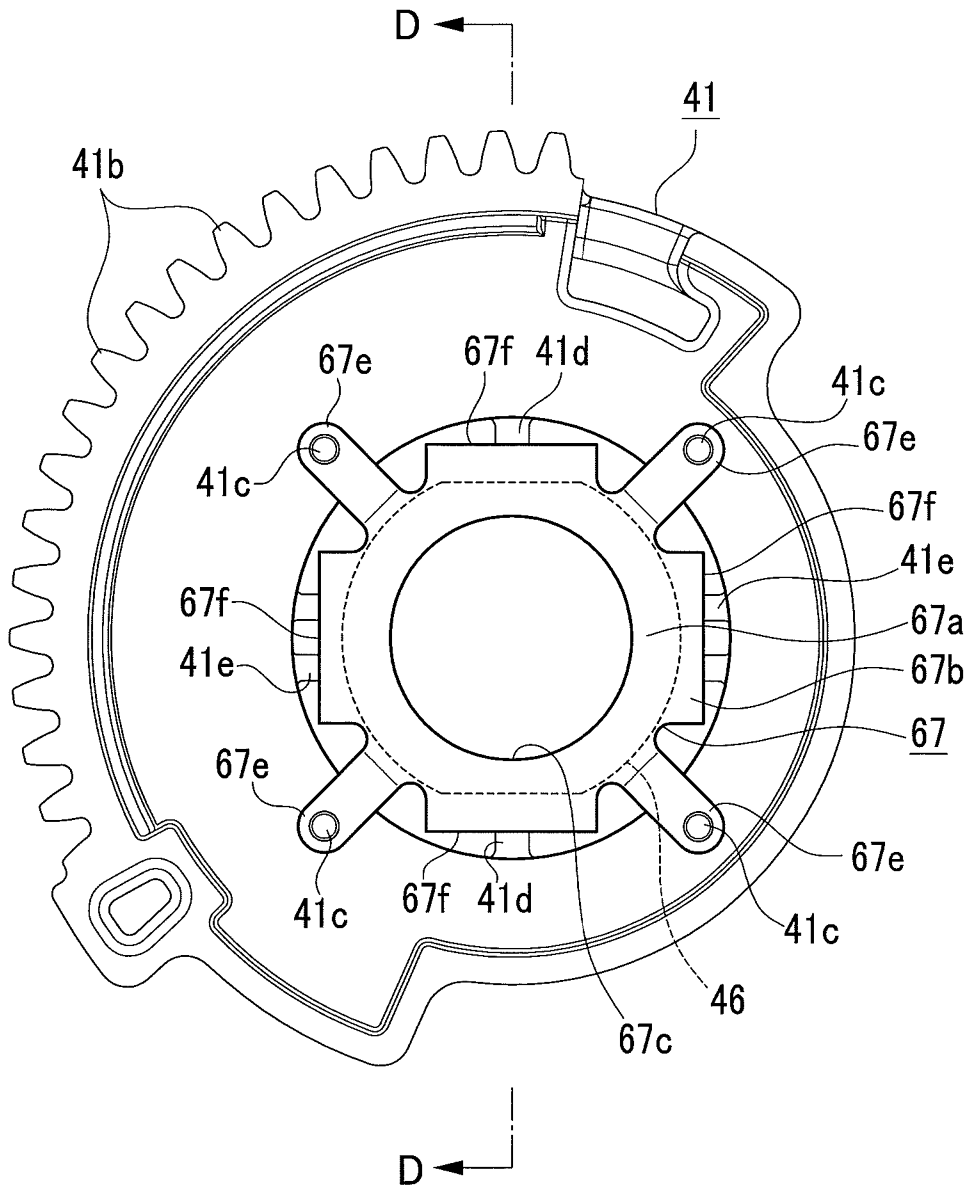
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FIG. 31

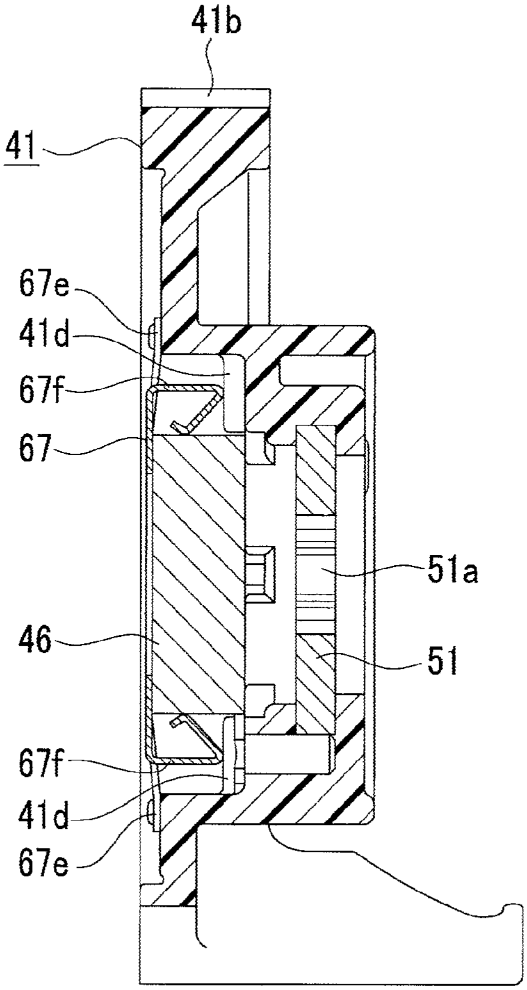

FIG. 32

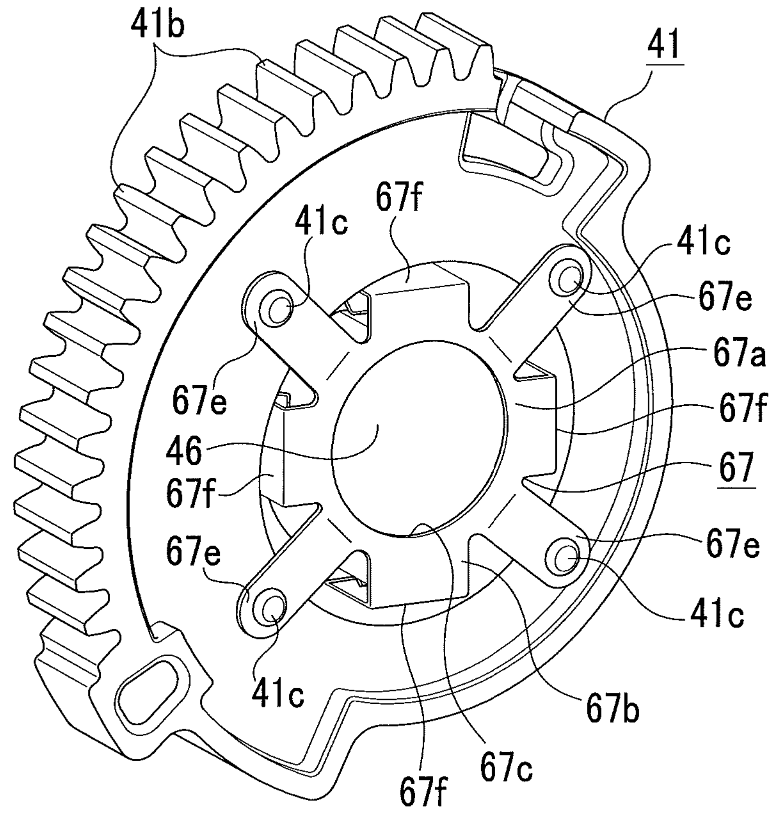
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FIG. 33

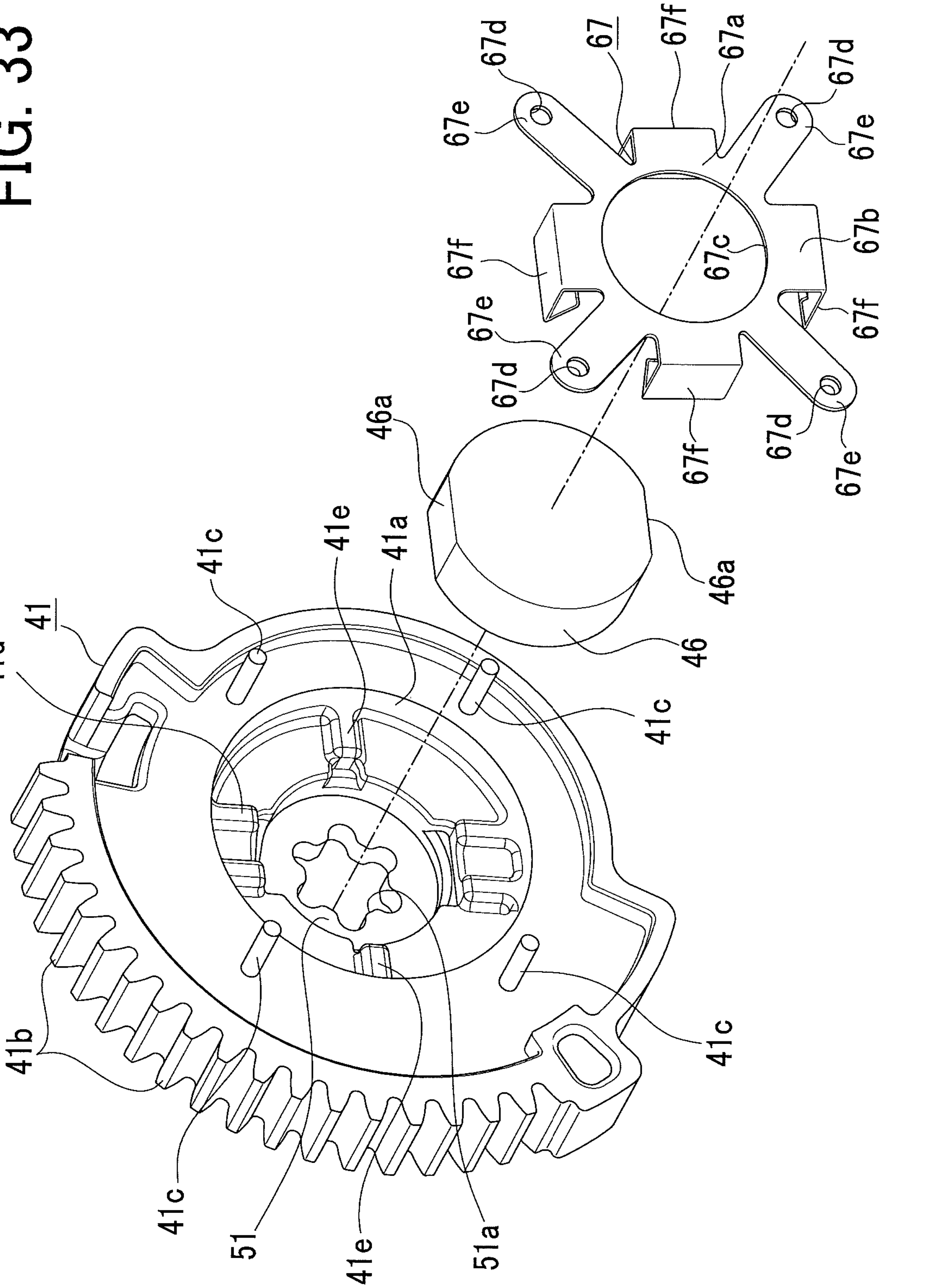


FIG. 34

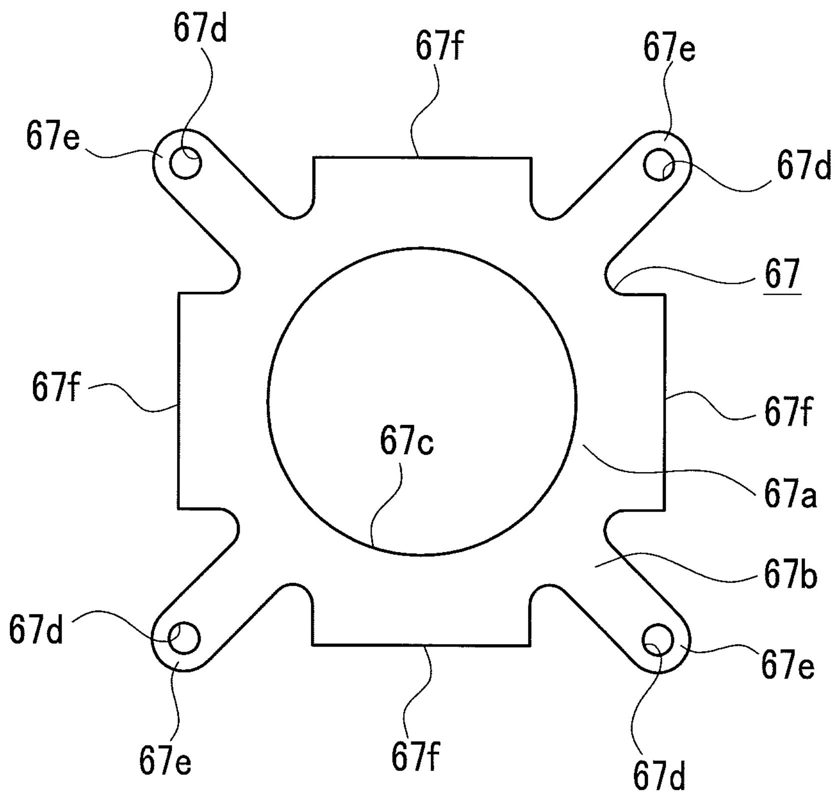
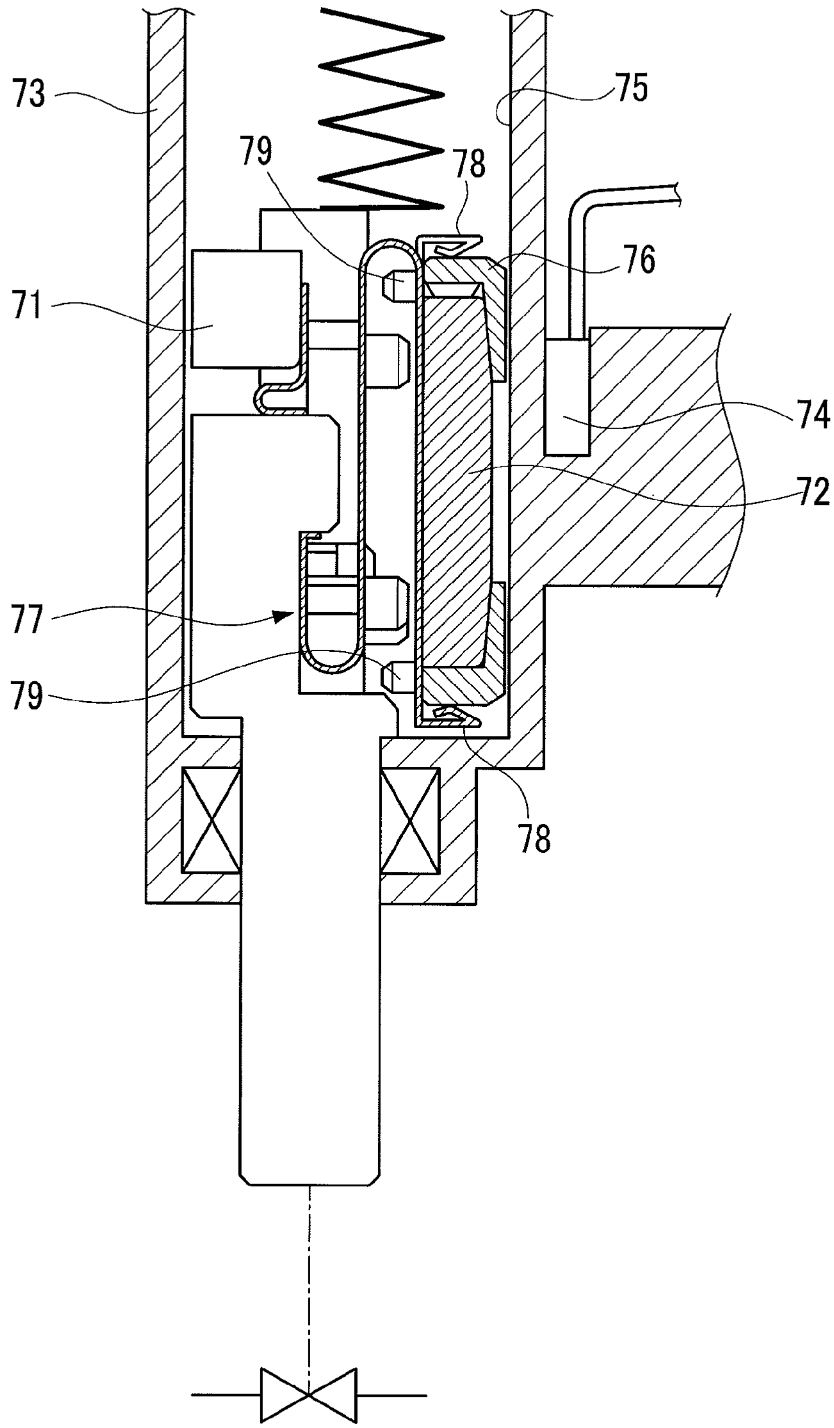


FIG. 35 Related Art



ROTATION ANGLE DETECTION APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the benefit of priority from the prior Japanese Patent Application No. 2014-104691 filed on May 20, 2014, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a rotation angle detection apparatus configured to detect a rotation angle of a rotor.

2. Related Art

Heretofore, for this type of technique, for example, a movement detection apparatus disclosed in JP-A-2011-17598 has been known. FIG. **35** is a cross sectional view of this apparatus. The apparatus includes a moving part **71**, a magnet **72** which will move with the moving part **71**, a magnetism detector **74** arranged in a housing **73** to detect leakage magnetic field leaking from the magnet **72**, a sliding holder **76** configured to retain the magnet **72** and to slide on a guide surface **75** provided in the housing **73**, and a connection member **77** positioned in between the moving part **71** and the sliding holder **76** to press the sliding holder **76** toward the guide surface **75**. The connection member **77** is provided with holding parts **78** holding the sliding holder **76** from both sides of the holder **76**, the both sides opposite each other in a sliding direction. The connection member **77** is made of non-magnetic material for spring. The magnet **72** is pressed toward the sliding holder **76** by a supplementary press piece (not shown) formed in the connection member **77**. The sliding holder **76** includes positioning projections **79** inserted in support holes (not shown) of the connection member **77** and the positioning projections **79** are thermally caulked so that the sliding holder **76** is secured to the connection member **77**. The sliding holder **76**, the magnet **72**, and the connection member **77** are integrally assembled to complete an assembly body and thus the movement detection apparatus is configured. This Japanese Application Publication JP-A-2011-17598 discloses the technique of retaining the magnet **72** without wobbling in an axial direction.

SUMMARY OF INVENTION

Problems to be Solved by the Invention

However, in the apparatus disclosed in JP-A-2011-17598, the connection member **77** has only a force to press the magnet **72** in the axial direction. Therefore, in order to restrict the magnet **72** from moving in a direction orthogonal to the axial direction, the magnet **72** needs to be press-fitted in the sliding holder **76**, requiring a complicated structure of the sliding holder **76**, that is difficult to manufacture.

The present invention has been made in view of the above circumstances and has a purpose to provide a rotation angle detection apparatus with a simple structure, the apparatus being capable of retaining a magnet with respect to a rotor which retains the magnet without wobbling in an axial direction and in a radial direction.

Means of Solving the Problems

To achieve the above purpose, one aspect of the invention provides a rotation angle detection apparatus provided with: a rotor; a magnet retained in the rotor; and a magnetism detector positioned to face to the magnet, the rotation angle detection apparatus being configured to detect a rotation angle of the rotor in such a way that the magnet rotates integrally with the rotor and the magnetism detector detects changes in magnetic field of the magnet, wherein the rotor includes a bottomed recessed part and a plurality of mounting pins arranged in the recessed part, the magnet is inserted in the recessed part such that a part of the magnet protrudes from an upper end of the recessed part, the rotation angle detection apparatus includes an elastically deformable retaining plate made of non-magnetic material configured to press and hold the magnet inserted in the recessed part to the rotor, the retaining plate includes a center portion and an outer portion, the outer portion including a plurality of mounting holes in each of which the mounting pins are inserted, and the magnet inserted in the recessed part is pressed at an outer peripheral edge against the rotor by the elastically deformed retaining plate and each of the mounting pins inserted one in each of the mounting holes is thermally caulked so that the magnet is secured to the rotor.

Effects of the Invention

According to the present invention, with respect to a rotor retaining a magnet, the magnet can be retained without wobbling in an axial direction and in a radial direction with a simple structure.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view showing an electrically-operated EGR valve provided with a double offset valve in a first embodiment;

FIG. **2** is a partially broken perspective view showing a valve part in a valve full-closed state that a valve element seats on a valve seat in the first embodiment;

FIG. **3** is a partially broken perspective view showing the valve part in a valve full-opened state that the valve element is separated most from the valve seat in the first embodiment;

FIG. **4** is a plan sectional view showing the EGR valve in the first embodiment;

FIG. **5** is a rear view showing a state that an end frame is removed from a valve housing in the first embodiment;

FIG. **6** is a front view showing an inside part of the end frame in the first embodiment;

FIG. **7** is a front view showing a state that a magnet is mounted in a main gear in the first embodiment;

FIG. **8** is a cross-sectional view taken along a line A-A in FIG. **7**, showing a state that the magnet is mounted in the main gear in the first embodiment;

FIG. **9** is a perspective view showing a state that the magnet is mounted in the main gear in the first embodiment;

FIG. **10** is an exploded perspective view showing a way of mounting the magnet in the main gear in the first embodiment;

FIG. **11** is a front view of the magnet in the first embodiment;

FIG. **12** is a front view of a retaining plate in the first embodiment;

FIG. **13** is an exploded perspective view showing a configuration of the retaining plate in the first embodiment;

FIG. **14** is a front view showing a state that a magnet is mounted in a main gear in a second embodiment;

FIG. **15** is a cross-sectional view taken along a line B-B in FIG. **14**, showing a state that the magnet is mounted in the main gear in the second embodiment;

FIG. **16** is an enlarged sectional view of a portion indicated with a chain-dotted circle in FIG. **15** in the second embodiment;

FIG. **17** is a front view of a retaining plate in a third embodiment;

FIG. **18** is a left-side view of the retaining plate in the third embodiment;

FIG. **19** is a perspective view of the retaining plate seen from a front side in the third embodiment;

FIG. **20** is a perspective view of the retaining plate seen from a rear side in the third embodiment;

FIG. **21** is a front view of a retaining plate in a fourth embodiment;

FIG. **22** is a left-side view of the retaining plate in the fourth embodiment;

FIG. **23** is a perspective view of the retaining plate seen from a front side in the fourth embodiment;

FIG. **24** is a perspective view of the retaining plate seen from a rear side in the fourth embodiment;

FIG. **25** is a front view showing a state that a magnet is mounted in a main gear in a fifth embodiment;

FIG. **26** is a cross-sectional view taken along a line C-C in FIG. **25**, showing a state that the magnet is mounted in the main gear in the fifth embodiment;

FIG. **27** is a perspective view showing a state that the magnet is mounted in the main gear in the fifth embodiment;

FIG. **28** is an exploded perspective view showing a way of mounting the magnet in the main gear in the fifth embodiment;

FIG. **29** is a front view of the retaining plate in the fifth embodiment;

FIG. **30** is a front view showing a state that a magnet is mounted in a main gear in a sixth embodiment;

FIG. **31** is a cross-sectional view taken along a line D-D in FIG. **30**, showing a state that the magnet is mounted in the main gear in the sixth embodiment;

FIG. **32** is a perspective view showing a state that the magnet is mounted in the main gear in the sixth embodiment;

FIG. **33** is an exploded perspective view showing a way of mounting the magnet in the main gear in the sixth embodiment;

FIG. **34** is a front view of the retaining plate in the sixth embodiment; and

FIG. **35** is a sectional view of a movement detection apparatus according to a related art.

DESCRIPTION OF EMBODIMENTS

First Embodiment

A detailed description of a first embodiment of a rotation angle detection apparatus of the present invention embodied as an exhaust gas recirculation valve (EGR valve) provided with a double offset valve will now be given referring to the accompanying drawings.

FIG. **1** is a perspective view showing an electrically-operated EGR valve **1** provided with a double offset valve. This EGR valve **1** includes a valve part **2** configured as the double offset valve, a motor part **3** internally provided with a motor **32** (see FIG. **4**), and a reduction mechanism part **4** internally provided with a plurality of gears **41** to **43** (see FIGS. **4** and **5**). The valve part **2** includes a pipe **12** having a passage **11** in which EGR gas as a fluid flows. In this passage **11**, a valve seat **13**, a valve element **14**, and a rotary shaft **15** are arranged. The rotary shaft **15** is configured to receive torque of the motor **32** (see FIG. **4**) via the plurality of gears **41** to **43** (see FIGS. **4** and **5**).

FIG. **2** is a partially broken perspective view of the valve part **2** in a valve fully-closed state that the valve element **14** seats on the valve seat **13**. FIG. **3** is a partially broken perspective view of the valve part **2** in a valve fully-opened state that the valve element **14** is separated most from the valve seat **13**. As shown in FIGS. **2** and **3**, the passage **11** is formed with a step portion **10** in which the valve seat **13** is fitted. The valve seat **13** is formed in a circularly annular shape and formed in its center with a valve hole **16**. A peripheral portion of the valve hole **16** is formed with an annular seat surface **17**. The valve element **14** formed in a disc-like shape is formed on its outer circumference with an annular sealing surface **18** corresponding to the seat surface **17**. The valve element **14** is fixed to the rotary shaft **15** so that the valve element **14** rotates integrally with the rotary shaft **15**. In FIGS. **2** and **3**, the passage **11** directly above the valve element **14** indicates an upstream side of the EGR gas flow, and the passage **11** directly below the valve seat **13** indicates a downstream side of the EGR gas flow. Namely, the valve element **14** is located upstream of the EGR gas flow than the valve seat **13** in the passage **11**.

FIG. **4** is a plan sectional view of the EGR valve **1**. The EGR valve **1** includes main elements of, as well as the rotary shaft **15** and the valve element **14**, an EGR body **31**, the motor **32**, a reduction mechanism **33**, and an opener mechanism **34**.

In the present embodiment, the EGR body **31** includes an aluminum-made valve housing **35**, including the passage **11** and the pipe **12**, and a synthetic-resin-made end frame **36** closing an opening end of the valve housing **35**. The rotary shaft **15** and the valve element **14** are provided in the valve housing **35**. The rotary shaft **15** includes a pin **15***a* protruding from a distal end of the shaft **15**. A distal end side of the rotary shaft **15** where the pin **15***a* is provided is a free end, and this distal end is inserted and positioned in the passage **11** of the pipe **12**. Further, the rotary shaft **15** is cantilevered in a rotatable manner with respect to the valve housing **35** via two bearings of a first bearing **37** and a second bearing **38** which are arranged apart from each other on a proximal end side of the rotary shaft **15**. The first bearing **37** consists of a ball bearing and the second bearing **38** consists of a needle bearing. The valve element **14** is fixed to the pin **15***a* formed on the distal end of the rotary shaft **15** by welding an extending portion **14***b* and arranged in the passage **11**.

FIG. **5** is a rear view of the valve housing **35** in a state that the end frame **36** is removed. FIG. **6** is a front view of an inside part of the end frame **36**. The end frame **36** is fixed to the valve housing **35** by a plurality of rivets or clips (not shown). As shown in FIGS. **4** and **6**, an EGR opening-degree sensor **39** is provided inside the end frame **36** in correspondence with the proximal end of the rotary shaft **15** and used for detecting an opening degree of the valve element **14** (EGR opening degree). This sensor **39** is configured by an MR-IC, a hall-IC, or the like, to detect a rotation angle of the rotary shaft **15** as the EGR opening degree. As shown in FIGS. **4** and **5**, a main gear **41** made of a fan-shaped gear is fixed to the proximal end of the rotary shaft **15**. A return spring **40** is provided in between the main gear **41** and the valve housing **35** to urge the valve element **14** in a valve-closing direction. The return spring **40** is one of elements constituting the opener mechanism **34**. A bottomed recessed part **41***a* is formed on a rear side of the main gear **41** to accommodate an almost disc-like shaped magnet **46**. The magnet **46** is pressed and fixed by a retaining plate **47**. Accordingly, when the main gear **41** is rotated integrally with the valve element **14** and the rotary shaft **15**, the magnet **46** also rotates, thereby changing a magnetic field. Then, the EGR opening-degree sensor **39** detects the changes in the magnetic field of the magnet **46**, and thereby the rotation angle of the main gear **41** is detected as the rotation angle of the valve element **14**, i.e., the EGR opening degree. In the present embodiment, the main gear **41** corresponds to one example of a rotor of the invention, and the EGR opening-degree sensor **39** corresponds to one example of a magnetism detector of the invention. Further, the rotation angle detection apparatus of the present invention consists of the main gear **41**, the magnet **46**, and the EGR opening-degree sensor **39**.

In the present embodiment, the motor **32** is accommodated and fixed in an accommodation chamber **35***a* formed in the valve housing **35**. To be specific, the motor **32** accommodated in the accommodation chamber **35***a* is fixed to the valve housing **35** via a holding plate **48** and a plate spring **49** provided on both ends of the chamber **35***a*. The motor **32** is drivingly connected to the rotary shaft **15** via the reduction mechanism **33** for driving the valve element **14** to open and close. On an output shaft **32***a* of the motor **32**, a motor gear **43** is mounted. This motor gear **43** is drivingly connected to the main gear **41** via an intermediate gear **42**. The intermediate gear **42** is a two-step gear including a large-diameter gear **42***a* and a small-diameter gear **42***b* and is rotatably supported in the valve housing **35** via a pin shaft **44**. The large-diameter gear **42***a* engages with the motor gear **43** and the small-diameter gear **42***b* engages with the main gear **41**. In the present embodiment, as each of the gears **41** to **43** configuring the reduction mechanism **33**, resin gears made of resin material are adopted for weight reduction.

As shown in FIG. **4**, a rubber-made gasket **50** is provided between the valve housing **35** and the end frame **36**. The gasket **50** is placed in a circumferential groove **36***a* formed on an outer circumference in an open end face of the end frame **36** as shown in FIG. **6**. In this manner, the gasket **50** is interposed between the valve housing **35** and the end frame **36**, and thereby the inside of the motor part **3** and the reduction mechanism part **4** is hermetically closed from an atmosphere.

Accordingly, as shown in FIG. **2**, in the valve fully-closed state of the valve element **14**, the motor **32** is energized and operated to rotate the output shaft **32***a* in a forward direction and the motor gear **43** is rotated accordingly. The rotation of the motor gear **43** is reduced by the intermediate gear **42** and transmitted to the main gear **41**. Thereby, the rotary shaft **15** and the valve element **14** are rotated against urging force of the return spring **40** to open the passage **11**. Namely, the valve element **14** is opened. In order to keep a certain opening degree of the valve element **14**, the motor **32** is energized to generate a torque and the torque as a retaining force is transmitted to the rotary shaft **15** and to the valve element **14** via the motor gear **43**, the intermediate gear **42**, and the main gear **41**. This retaining force is balanced with the urging force of the return spring **40** so that the opening degree of the valve element **14** is maintained to a certain degree.

Next, a rotation angle detection apparatus in the present embodiment is explained in detail. FIG. **7** is a front view showing a state that the magnet **46** is mounted in the main gear **41**. FIG. **8** is a cross-sectional view taken along a line A-A in FIG. **7**, showing a state that the magnet **46** is mounted in the main gear **41**. FIG. **9** is a perspective view showing a state that the magnet **46** is mounted in the main gear **41**. FIG. **10** is an exploded perspective view showing a way of mounting the magnet **46** in the main gear **41**. As shown in FIGS. **7** to **10**, the main gear **41** has a plurality of teeth **41***b* on an outer circumference. The main gear **41** includes a bottomed recessed part **41***a* and four mounting pins **41***c* arranged around the recessed part **41***a* on one end face of the main gear **41** opposite to the other end face to which the proximal end of the rotary shaft **15** is fixed. Each of the mounting pins **41***c* is integrally formed in the resin-made main gear **41** and equally spaced apart from each other (by 90 degrees) about an axis of the main gear **41**.

As shown in FIG. **10**, the recessed part **41***a* is formed with a bottom **41***aa* provided integrally on its center with a fixing plate **51** for fixing the rotary shaft **15**. The fixing plate **51** is formed with a deformed hole **51***a* to be connected to the proximal end of the rotary shaft **15**. The bottom **41***aa* of the recessed part **41***a* is formed with four groups of ribs **41***d* and **41***e* extending in a radial direction. The ribs **41***d* and **41***d* are arranged corresponding to the location of the respective mounting pins **41***c*. Each of the two groups of the ribs **41***d* opposite each other in a vertical direction includes two ribs arranged side by side in parallel to each other in FIG. **10**. Each of the two groups of the ribs **41***e* opposite each other in a lateral direction in FIG. **10** includes one rib. A length of each of the ribs **41***d* and **41***e* in the radial direction of the bottom **41***aa* is made shorter than a length of the bottom **41***aa* in the radial direction. In correspondence with each of the four groups of ribs **41***d* and **41***e*, the main gear **41** is formed on its end face with chevron-like sunken portions **41***f*. The mounting pins **41***c* are positioned one in each of the sunken portions **41***f*.

FIG. **11** is a front view of the magnet **46**. As shown in FIGS. **10** and **11**, the magnet **46** is formed in an almost disc-like shape and a height (thickness) of the magnet **46** is made larger than a depth of the bottom **41** *as* of the recessed part **41***a* of the main gear **41**. The magnet **46** has two width across flat surfaces **46***a* on its outer circumference. When the magnet **46** is inserted in the recessed part **41***a*, these surfaces **46***a* are arranged to face to the end faces of the ribs **41***d* opposite each other in the vertical direction in FIG. **10**.

FIG. **12** is a front view of the retaining plate **47**. FIG. **13** is an exploded perspective view showing a configuration of the retaining plate **47**. The retaining plate **47** is configured to press and hold the magnet **46** inserted in the recessed part **41***a* against the main gear **41** as shown in FIG. **10**. The retaining plate **47** is formed of spring material, such as stainless steel or phosphor bronze as non-magnetic material, and rubber material so that the plate **47** is elastically deformable. As shown in FIGS. **10** and **12**, the overall retaining plate **47** is of almost cross-shape, including a center portion **47***a* for holding the magnet **46** and outer portions **47***b* extending radially outward in four directions from the center portion **47***a*. The center portion **47***a* is formed with a center opening **47***c*. The outer portions **47***b* are formed with four mounting holes **47***d* in which each mounting pin **41***c* is inserted. The outer portions **47***b* are four separate vane portions **47***e*. In the present embodiment, as shown in FIG. **13**, the retaining plate **47** includes a rubber member **53** of an identical shape with the center portion **47***a*, and this rubber member **53** is attached to the center portion **47***a* on a side facing to the magnet **46**. By providing the rubber member **53** on the center portion **47***a*, a surface of the center portion **47***a* of the retaining plate **47** has relatively high frictional coefficient. Thus, the surface of the center portion **47***a* of the retaining plate **47** has skidproof (anti-slip) effect.

As shown in FIG. **10**, the magnet **46** is inserted in the recessed part **41***a* such that a part of the magnet **46** protrudes from an upper end of the recessed part **41***a* of the main gear **41**. Then, as shown in FIGS. **7** to **10**, the magnet **46** inserted in the recessed part **41***a* is pressed at an outer peripheral edge against the main gear **41** by the elastically deformed retaining plate **47**. In this state, each of the mounting pins **41***c* inserted one in each of the mounting holes **47***d* is thermally caulked so that the magnet **46** is secured to the main gear **41**.

According to the above explained EGR valve **1** configured with the double offset valve of the present embodiment, the valve element **14** is rotated around an axial line of the rotary shaft **15**, and thereby the sealing surface **18** of the valve element **14** is moved between a valve-fully-closed position in which the sealing surface **18** is in surface-contact with the seat surface **17** of the valve seat **13** and a valve-fully-opened position in which the sealing surface **18** is separated most from the seat surface **17**. In the state that the valve element **14** is placed in the valve-fully-closed position, namely in the valve-fully-closed state of the EGR valve **1**, the valve hole **16** of the valve seat **13** is closed by the valve element **14**, so that the EGR gas flow is shut off at the valve hole **16**. Further, a portion between the valve element **14** and the valve seat **13** is sealed by the surface contact of the sealing surface **18** and the seat surface **17**, thus preventing leakage of the EGR gas without providing any special elastic part or member for pressing down the valve seat **13** onto the valve element **14**. Specifically, without providing any special elastic part or member, sealing property of the EGR valve **1** in the valve-fully-closed state can be ensured only by the configuration of the seat surface **17** of the valve seat **13** and the sealing surface **18** of the valve element **14**.

In the valve-opened state of the EGR valve **1**, the valve hole **16** of the valve seat **13** is opened and the EGR gas is allowed to flow through the valve hole **16**. Further, when the valve element **14** starts to rotate in a valve-opening direction from the valve-fully-closed position, the sealing surface **18** of the valve element **14** starts to separate from the seat surface **17** of the valve seat **13** and starts to move along a rotation trail centered about the axial line of the rotary shaft **15**, thus minimizing rubs between the sealing surface **18** and the seat surface **17**. As a result, the valve element **14** can be swiftly rotated in valve opening to an extent that rubs between the valve element **14** and the valve seat **13** become minute, leading to reduction in friction between the sealing surface **18** and the seat surface **17**. Consequently, the EGR valve **1** can achieve improved valve-opening responsiveness and durability with a simple structure without providing any special elastic part or member.

According to the rotation angle detection apparatus in the present embodiment, the magnet **46** inserted in the recessed part **41***a* of the main gear **41** is pressed at an outer peripheral edge onto the main gear **41** by an elastic force of the retaining plate **47**. Thereby, the magnet **46** can be held in the main gear **41** without wobbling in the axial direction and the radial direction with a simple structure of the retaining plate **47**.

Further in the present embodiment, the retaining plate **47** includes the center portion **47***a* pressing down the magnet **46** and the outer portions **47***b* include the plurality of vane portions **47***e* located one in each of the mounting holes **47***d*. Therefore, the force pressing the magnet **46** against the main gear **41** acts on the peripheral edge of the magnet **46** through the plurality of vane portions **47***e* located in outer portion of the retaining plate **47**. Accordingly, movement of the magnet **46** in the main gear **41** in the radial direction can be especially restricted, enhancing a retaining force of the magnet **46** in a fixed position.

Moreover, according to the present embodiment, the magnet **46** is pressed against the main gear **41** by the center portion **47***a* of the retaining plate **47**, thereby providing skidproof effect between the center portion **47***a* and a surface of the magnet **46**, so that the magnet **46** hardly moves in the axial and radial directions. Accordingly, the movement of the magnet **46** in the main gear **41** in the axial and radial directions can be further restricted, further enhancing the retaining force of the magnet **46** in the fixed position.

In the present embodiment, the retaining plate **47** is secured to the main gear **41** not by bonding but by thermally caulking each of the mounting pins **41***c*. Thereby, a period of time for mounting the magnet **46** in the main gear **41** can be made shorter than a case of mounting the magnet by bonding. Further, since a part of the retaining plate **47** is thermally caulked to secure the magnet **46** to the main gear **41**, a thermal load is not directly transmitted to the magnet **46** and thus the magnet **46** is not influenced by thermal change during fixation and after the fixation.

Second Embodiment

A second embodiment of a rotation angle detection apparatus of the present invention embodied as an EGR valve provided with a double offset valve is now explained referring to the accompanying drawings.

In the following embodiment, similar or identical elements to those in the first embodiment are given the same reference signs as in the first embodiment, and the following explanation will be made with a focus on differences from the first embodiment.

The second embodiment is different from the first embodiment as for a configuration of the main gear **41**. FIG. **14** is a front view showing a state that the magnet **46** is mounted in the main gear **41**. FIG. **15** is a cross-sectional view taken along a line B-B in FIG. **14**, showing a state that the magnet **46** is mounted in the main gear **41**. FIG. **16** is an enlarged sectional view of a chain-dotted circle Si in FIG. **15**. As shown in FIG. **14**, the recessed part **41***a* of the main gear **41** is formed with four sunken portions **41***f* around the recessed part **41***a*, and a chevron-like upward projecting curve of each of the sunken portions **41***f* is formed with a lock portion **41***g* protruding radially inwardly in the sunken portion **41***f* like a flange. The lock portions **41***g* are integrally formed in the main gear **41**. As shown in FIGS. **14** to **16**, each of the lock portions **41***g* is arranged to restrict spring back of each vane portion **47***e* of the retaining plate **47**, and a distal outer edge of each of the vane portions **47***e* comes under the lock portion **41***g* so that the vane portions **47***e* are locked by the lock portions **41***g*.

Therefore, according to the second embodiment, even if the mounting pins **41***c* thermally caulked to the main gear **41** are broken by any chance, the outer portions **47***b* of the retaining plate **47**, i.e., the distal outer edge of each of the vane portions **47***e* remains engaged with the corresponding lock portions **41***g* and thus the retaining plate **47** is not disengaged from the main gear **41**. As a result, even if each of the thermally caulked mounting pins **41***c* is broken by any chance, the magnet **46** can be held in the main gear **41**, ensuring the function as the rotation angle detection apparatus.

Third Embodiment

A third embodiment of a rotation angle detection apparatus of the present invention embodied as an EGR valve provided with a double offset valve is now explained referring to the accompanying drawings.

The third embodiment is different from the foregoing embodiments as for a configuration of the retaining plate **47**. FIG. **17** is a front view of the retaining plate **47**. FIG. **18** is a left-side view of the retaining plate **47**. FIG. **19** is a perspective view of the retaining plate **47** seen from a front side. FIG. **20** is a perspective view of the retaining plate **47** seen from a rear side. As shown in FIGS. **17** to **20**, the retaining plate **47** is formed with a plurality of elastically deformable hook portions **47***f* for clamping a peripheral surface of the magnet **46** in a state that the magnet **46** is pressed against the main gear **41**. Each hook portion **47***f* is formed by partially cutting and bending an inner peripheral part around a center opening **47***c* of the center portion **47***a* of the retaining plate **47** into a tongue-like shape, and the hook portions **47***f* are bent toward a rear side in correspondence with the location of each of the vane portions **47***e*. In the third embodiment, the retaining plate **47** is made of non-magnetic metal to be elastically deformable. Therefore, each hook portion **47***f* is also elastically deformable. In this third embodiment, each hook portion **47***f* is bent at right angle with respect to the center portion **47***a* and the vane portions **47***e*. Specifically, when the retaining plate **47** is attached on the magnet **46** inserted in the recessed part **41***a* of the main gear **41**, each hook portion **47***f* is not in contact with the peripheral surface of the magnet **46**. Thereafter, when the magnet **46** is pressed by the retaining plate **47** and each of the vane portions **47***e* is thermally caulked with the mounting pins **41***c*, the vane portions **47***e* are inclined toward the mounting pins **41***c*. As a result, this inclination of the vane portions **47***e* leads to inward inclination of the hook portions **47***f* toward the magnet **46** to have the surface contact with the peripheral surface of the magnet **46**, so that the magnet **46** is held with an elastic force.

According to the third embodiment, the side faces of the magnet **46** are held by the plurality of hook portions **47***f* with the elastic force in a state that the magnet **46** is pressed against the main gear **41** by the retaining plate **47**. Thus, the movement of the magnet **46** in the radial direction in the main gear **41** can be further restricted, further enhancing the retained state of the magnet **46** in the fixed position.

Fourth Embodiment

A fourth embodiment of a rotation angle detection apparatus of the present invention embodied as an EGR valve provided with a double offset valve is now explained referring to the accompanying drawings.

The fourth embodiment is different from the third embodiment as for a configuration of the hook portion **47***f* of the retaining plate **47**. FIG. **21** is a front view of the retaining plate **47**. FIG. **22** is a left-side view of the retaining plate **47**. FIG. **23** is a perspective view of the retaining plate **47** seen from a front side. FIG. **24** is a perspective view of the retaining plate **47** seen from a rear side. As shown in FIGS. **21** to **24**, in the fourth embodiment, each hook portion **47***f* is bent in a V-shape (an inverted L-shape) tilting toward a center of the retaining plate **47**. Accordingly, when the magnet **46** is pressed down by the retaining plate **47**, a bent portion **47***fa* of each of the hook portions **47***f* comes to contact with the peripheral surface of the magnet **46**.

According to the fourth embodiment, the hook portions **47***f* are each bent and the bent portions **47***fa* come to contact with the peripheral surface of the magnet **46**, so that the peripheral surface of the magnet **46** is further firmly held with an elastic force of the bent portions **47***fa* of the hook portions **47***f* Thereby, the movement of the magnet **46** in the main gear **41** in the radial direction is further surely restricted, further enhancing the retained state of the magnet **46** in the fixed position. Moreover, since the hook portions **47***f* are in contact with the peripheral surface of the magnet **46** through the respective bent portions **47***fa*, the magnet **46** is not scratched by the hook portions **47***f*.

Fifth Embodiment

A fifth embodiment of a rotation angle detection apparatus of the present invention embodied as an EGR valve provided with a double offset valve is now explained referring to the accompanying drawings.

In the fifth embodiment, a configuration of a retaining plate **57** is different from that in the foregoing embodiments. FIG. **25** is a front view showing a state that the magnet **46** is mounted in the main gear **41**. FIG. **26** is a cross-sectional view taken along a line C-C in FIG. **25**, showing the state that the magnet **46** is mounted in the main gear **41**. FIG. **27** is a perspective view showing a state that the magnet **46** is mounted in the main gear **41**. FIG. **28** is an exploded perspective view showing a way of mounting the magnet **46** in the main gear **41**. FIG. **29** is a front view of the retaining plate **57**.

As shown in FIG. **29**, the retaining plate **57** of the fifth embodiment is formed in an almost square shape as a whole, and made of elastically-deformable non-magnetic metal. An outer portion **57***b* of the retaining plate **57** includes four elastically deformable vane portions **57***e*. Each of the vane portions **57***e* is formed in an almost chevron-like shape and formed with a mounting hole **57***d*. The retaining plate **57** is formed with a center opening **57***c* in a center portion **57***a* which is configured to press the magnet **46**. An inner periphery portion defining the center opening **57***c* is split into a plurality of elastically deformable tongue pieces **57***f*.

As shown in FIG. **28**, an end face of the main gear **41** is provided with a plurality of mounting pins **41***c* protruding in locations one in each of the mounting holes **57***d* of the retaining plate **57**. In the fifth embodiment, the sunken portion **41***f* shown in FIG. **10** and others is not provided in portions where the mounting pins **41***c* are arranged.

As shown in FIG. **28**, the magnet **46** is inserted in the recessed part **41***a* such that a part of the magnet **46** protrudes from an upper end of the recessed part **41***a* of the main gear **41**. Then, as shown in FIGS. **25** to **28**, the magnet **46** inserted in the recessed part **41***a* is pressed against the main gear **41** in a manner that each of the tongue pieces **57***f* of the retaining plate **57** is elastically deformed, and the respective mounting pins **41***c* are inserted in the corresponding mounting holes **57***d* of the vane portions **57***e*. Finally, the mounting pins **41***c* are thermally caulked to secure the magnet **46** to the main gear **41**.

According to the rotation angle detection apparatus of the fifth embodiment, the magnet **46** inserted in the recessed part **41***a* of the main gear **41** is pressed to the main gear **41** with the elastic force of the retaining plate **57**. Thereby, in the main gear **41** retaining the magnet **46**, the magnet **46** can be held with a simple structure without wobbling in the axial and radial directions.

Further, according to the fifth embodiment, the pressing force pressing the magnet **46** against the main gear **41** acts on a center of the magnet **46** by the plurality of tongue pieces **57***f* of the center portion **57***a* of the retaining plate **57**. Accordingly, the movement of the magnet **46** in the main gear **41** in the radial direction can be especially restricted, thus enhancing the retaining force of the magnet **46** in the fixed position.

Sixth Embodiment

A sixth embodiment of a rotation angle detection apparatus of the present invention embodied as an EGR valve provided with a double offset valve is now explained referring to the accompanying drawings.

In the sixth embodiment, a configuration of a retaining plate **67** is different from the foregoing embodiments. FIG. **30** is a front view showing a state that the magnet **46** is mounted in the main gear **41**. FIG. **31** is a cross-sectional view taken along a line D-D in FIG. **30**, showing the state that the magnet **46** is mounted in the main gear **41**. FIG. **32** is a perspective view showing the state that the magnet **46** is mounted in the main gear **41**. FIG. **33** is an exploded perspective view showing a way of mounting the magnet **46** in the main gear **41**. FIG. **34** is a front view of a retaining plate **67**.

As shown in FIG. **34**, the retaining plate **67** is formed in an almost square shape as a whole, and made of elastically-deformable non-magnetic metal. An outer portion **67***b* of the retaining plate **67** includes four elastically deformable vane portions **67***e*. Each vane portion **67***e* is formed in a tongue-like shape, and formed inside with a mounting hole **67***d*. The retaining plate **67** is formed with a center opening **67***c* in a center portion **67***a* which is configured to press the magnet **46**. The retaining plate **67** is formed with four hook portions **67***f*, each of the hook portions **67***f* being located between the adjacent vane portions **67***e* of the outer portion **67***b*. Each of the hook portions **67***f* is bent at right angle toward the magnet **46** and further folded inwardly at its distal end.

As shown in FIG. **33**, an end face of the main gear **41** is provided with a plurality of mounting pins **41***c* protruding in correspondence with each mounting hole **67***d* of the retaining plate **67**. In the sixth embodiment, the sunken portion **41***f* shown in FIG. **10** and others is not provided in portions where the mounting pins **41***c* are arranged. Moreover, in this embodiment, the height of each of the ribs **41***d* and **41***e* is made lower than the height of the ribs **41***d* and **41***e* shown in FIG. **28** so that each hook portion **67***f* of the retaining plate **67** does not interfere with the corresponding ribs **41***d* and **41***e* formed on the recessed part **41***a* of the main gear **41**.

As shown in FIG. **33**, the magnet **46** is inserted in the recessed part **41***a* such that a part of the magnet **46** protrudes from an upper end of the recessed part **41***a* of the main gear **41**. Then, as shown in FIGS. **30** to **33**, the magnet **46** inserted in the recessed part **41***a* is pressed against the main gear **41** by elastically deforming the vane portions **67***e* of the retaining plate **67**, and each mounting pin **41***c* is inserted in the mounting holes **67***d* of the vane portions **67***e*. Each mounting pin **41***c* is thermally caulked and thereby the magnet **46** is secured to the main gear **41**. Further, when the magnet **46** is pressed to the retaining plate **67**, the folded distal ends of the hook portions **67***f* are press-contacted with the peripheral surface of the magnet **46**.

According to the rotation angle detection apparatus of the sixth embodiment, the magnet **46** inserted in the recessed part **41***a* of the main gear **41** is pressed to the main gear **41** by the elastic force of the retaining plate **67**. Therefore, the magnet **46** can be held in the main gear **41** with a simple structure without wobbling in the axial and radial directions.

Further, according to the sixth embodiment, the folded distal end of each of the hook portions **67***f* is in press-contact with the peripheral surface of the magnet **46**, and thereby the peripheral surface of the magnet **46** are firmly held by the plurality of the hook portions **67***f*. Accordingly, the movement of the magnet **46** in the main gear **41** in the radial direction can be further surely restricted, further enhancing the retaining force of the magnet **46** in the fixed position.

The present invention is not limited to the above embodiments and may be embodied as below without departing from the scope of its subject matter.

(1) In the above first embodiment, the retaining plate **47** is formed of spring material such as stainless steel or phosphor bronze, and the center portion **47***a* has skidproof effect on its surface by providing the rubber member **53** on the center portion **47***a*. As an alternate, the retaining plate may be made of rubber material to have the skidproof effect, or the retaining plate made of metal may have the file-processed surface to have the skidproof effect.

(2) In each of the above embodiments, only the surfaces of the center portions **47***a* and **57***a* of the retaining plates **47** and **57** are applied with a work for skidproof effect, but alternatively, overall the surface of the retaining plate may be applied with the skidproof work.

(3) In each of the above embodiments, the rotation angle detection apparatus of the present invention is embodied as an EGR valve, but alternatively, this rotation angle detection apparatus may be embodied as an electronic throttle valve provided in an intake passage of an engine.

INDUSTRIAL APPLICABILITY

This invention may be utilized for detecting a rotation angle of a rotor configuring a device such as an EGR valve and an electronic throttle device.

REFERENCE SIGNS LIST

39 EGR opening-degree sensor (Magnetism detector)
41 Main gear (Rotor)
41*a* Recessed part
41*c* Mounting pin
41*g* Lock portion
46 Magnet
47 Retaining plate
47*a* Center portion
47*b* Outer portion
47*d* Mounting hole
47*e* Vane portion
47*f* Hook portion
57 Retaining plate
57*a* Center portion
57*b* Outer portion
57*c* Center opening
57*d* Mounting hole
57*e* Vane portion
57*f* Tongue piece
67 Retaining plate
67*a* Center portion
67*b* Outer portion
67*c* Center opening
67*d* Mounting hole
67*e* Vane portion
67*f* Hook portion

What is claimed is:

1. A rotation angle detection apparatus provided with: a rotor; a magnet retained in the rotor; and a magnetism detector positioned to face to the magnet,

the rotation angle detection apparatus being configured to detect a rotation angle of the rotor in such a way that the magnet rotates integrally with the rotor and the magnetism detector detects changes in magnetic field of the magnet, wherein

the rotor includes a bottomed recessed part and a plurality of mounting pins arranged in the recessed part,

the magnet is inserted in the recessed part such that a part of the magnet protrudes from an upper end of the recessed part,

the rotation angle detection apparatus includes an elastically deformable retaining plate made of non-magnetic material configured to press and hold the magnet inserted in the recessed part to the rotor,

the retaining plate includes a center portion and an outer portion, the outer portion including a plurality of mounting holes in each of which the mounting pins are inserted, and

the magnet inserted in the recessed part is pressed at an outer peripheral edge against the rotor by the elastically deformed retaining plate and each of the mounting pins inserted one in each of the mounting holes is thermally caulked so that the magnet is secured to the rotor.

2. The rotation angle detection apparatus according to claim **1**, wherein

the retaining plate presses the magnet with the center portion, and

the outer portion includes a plurality of vane portions in correspondence with the mounting holes.

3. The rotation angle detection apparatus according to claim **2**, wherein the retaining plate includes a plurality of elastically deformable hook portions configured to clamp and hold a peripheral surface of the magnet in a state that the retaining plate presses the magnet against the rotor.

4. The rotation angle detection apparatus according to claim **3**, wherein the rotor is formed with a lock portion locking an outer edge of the outer portion of the retaining plate so as to restrict spring back of the outer portion.

5. The rotation angle detection apparatus according to claim **2**, wherein the retaining plate is applied with a skidproof work at least on a surface of the center portion.

6. The rotation angle detection apparatus according to claim **5**, wherein the rotor is formed with a lock portion locking an outer edge of the outer portion of the retaining plate so as to restrict spring back of the outer portion.

7. The rotation angle detection apparatus according to claim **2**, wherein the rotor is formed with a lock portion locking an outer edge of the outer portion of the retaining plate so as to restrict spring back of the outer portion.

8. The rotation angle detection apparatus according to claim **2**, wherein

the retaining plate includes the center portion formed with a center opening and an inner periphery portion defining the center opening is split into a plurality of tongue pieces.

9. The rotation angle detection apparatus according to claim **1**, wherein the retaining plate includes a plurality of elastically deformable hook portions configured to clamp and hold a peripheral surface of the magnet in a state that the retaining plate presses the magnet against the rotor.

10. The rotation angle detection apparatus according to claim **9**, wherein the rotor is formed with a lock portion locking an outer edge of the outer portion of the retaining plate so as to restrict spring back of the outer portion.

11. The rotation angle detection apparatus according to claim **1**, wherein the retaining plate is applied with a skidproof work at least on a surface of the center portion.

12. The rotation angle detection apparatus according to claim **11**, wherein the rotor is formed with a lock portion locking an outer edge of the outer portion of the retaining plate so as to restrict spring back of the outer portion.

13. The rotation angle detection apparatus according to claim **1**, wherein the rotor is formed with a lock portion locking an outer edge of the outer portion of the retaining plate so as to restrict spring back of the outer portion.

14. The rotation angle detection apparatus according to claim **1**, wherein,

the retaining plate is configured to press the magnet with the center portion formed with a center opening, and

an inner periphery portion defining the center opening is split into a plurality of tongue pieces.

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